ARS-BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture
Boise, Idaho

INTERIM REPORT NO. 6
Cooperative Agreement No. 14-11-0001-4162(N)

For Period January 1, 1975 to December 31, 1975

TO

Denver Service Center
Bureau of Land Management
U. S. Department of the Interior
Denver, Colorado

MARCH 1976

(NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.)

TABLE OF CONTENTS

INTRODUCTION

Cooperative watershed research between the Agricultural Research Service, U.S. Department of Agriculture, and the Bureau of Land Management, U.S. Department of the Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1961, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results from January 1 through December 31, 1975, as outlined in the work plan for F.Y. 1976. The report also describes the proposed activities and changes in objectives for consideration in the F.Y. 1977 work plan.

Data collection, processing, and analysis continued according to the F.Y. 1976 work plan and details of progress and accomplishments are described in each section of the report. Further information is contained in Northwest Watershed Research Center Annual Reports for 1972 and prior years, and in Interim Report Nos. 1, 2, 3, 4, and 5 of ARS-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 14-11-0001-4162(N).

As reported in the PRECIPITATION REPORT, the rain gage network was reduced in January to 25 dual gage sites. The criteria for selection of the current network were discussed in that section. Certain plots, microwatersheds, and watersheds were also placed on standby, since the servicing precipitation gage was removed. These sites are noted in the runoff and sediment report.

The motivation in the network change was twofold: First, to place more emphasis on data analysis and interpretation of results for application by user groups and agencies; and second, to insure that the highest priority research objectives are adequately supported by necessary watershed studies.

The Northwest Watershed Research Center is an element of the Utah-Idaho-Montana Area Office, Western Region, ARS, USDA. Its research program serves the Owyhee Plateau Area of the Columbia River Basin and similar Soil Conservation Problem Areas in the Northwest. Its present field program is centered in the Reynolds Creek Watershed, located 55 miles southwest of Boise.

The mission of the Northwest Watershed Research Center, in response to the needs of the region, is to conduct research within the following areas:

1. Developing techniques for inventorying snow accumulation, distribution, and water equivalent of continuous and isolated snowpacks.

Determining the factors affecting timing and rates of snowmelt and formulating alternative procedures for predicting or forecasting runoff from melting snow, rainfall, or both, where the ground may or may not be frozen.

2. Formulating and testing rangeland watershed models which interface models for precipitation, snowmelt, infiltration, ET, subsurface flow, and surface flow, for predicting or forecasting streamflow, water yield, and/or water balances.

3. Deriving and testing models for prediction of rangeland erosion, channel degradation and/or aggradation, and downstream sediment yield.

4. Developing water quality models for rangeland watersheds that combine runoff models, erosion and sediment yield models, and rangeland management models, which predict water quality parameters for in-stream and off-stream uses.

5. Establishing the effects of rangeland management systems on soils and range conditions and productivity.

STAFF

Aaron, Virginia M.	Hydrologic Technician (Perm., 35 hr/wk)	
Belknap, Stephen P.	Agricultural Research Technician (Plants)	5/11/75 - 11/8/75
Bendio, Ruric E.	Boise State University Cooperator - Technician	12/9/75 - Present
Brakensiek, Donald L.	Research Hydraulic Engineer (LL & RL)	
Burgess, Michael D.	Electronic Technician (Perm., 39 hr/wk)	
Butler, Donna M.	Supervisory Administrative Clerk	
Coon, Delbert L.	Hydrologic Technician	
Cox, Lloyd M.	Hydrologist	
Engelbert, Carrol D.	Hydrologic Technician	Resigned 5/20/75
Engleman, Roger L.	Mathematician	
Fischer, Jan M.	Biological Technician (Soils)	6/12/75 - 8/15/75
Gidley, Jess R.	Hydrologic Aid (Temp., 16 hr/wk)	
Hanson, Clayton L.	Agricultural Engineer	
Hermann, Ralph F.	Carpenter (Perm., 24 hr/wk)	
Herrington, Mary	Boise State University Cooperator - Technician	6/1/75 - 10/10/75
Hoagland, Roy M.	Automotive Mechanic	
Johnson, Clifton W.	Research Hydraulic Engineer	
Morris, Ronald P.	Hydrologic Technician	
Perkins, Lee	Hydrologic Technician	
Robertson, David C.	Hydrologic Technician	
Schumaker, Gilbert A.	Soil Scientist	
Smith, Jeffrey P.	Hydrologic Technician	10/12/75 - Present
Smith, Rona G.	Clerk Typist (Temp., 16 hr/wk)	Resigned 8/20/75
Stephenson, Gordon R.	Geologist	
Street, Leah V.	Boise State University Cooperator - Technician	1/6/75 - 9/9/75
Street, Leah V.	Biological Technician (Soils)	9/14/75 - Presently Intermittent
Thomson, Michael S.	Hydrologic Aid (Temp., 16 hr/wk)	
Trautman, Kenneth W.	Engineering Equipment Operator	
Walton, Dala S.	Clerk Stenographer (Perm., 35 hr/wk)	
Wilson, Glenna A.	Procurement Clerk	
Zuzel, John F.	Hydrologist	

PRECIPITATION

Title: Precipitation characteristics of a northern, mountainous, semiarid watershed.

Personnel Involved:

John F. Zuzel, Hydrologist	Plans, designs, supervises data collection, analyses, and reports on research.
David C. Robertson, Hydrologic Technician	Assists in planning and supervision of data collection and analyses.

Date of Initiation: June 1961

Expected Termination Date: Continuing

INTRODUCTION

No dense, recording rain gage network existed in the Northwest prior to establishment of the Northwest Watershed Research Center. Such a network is necessary to delineate thunderstorms and storm variability. National Weather Service data collection stations are generally located in or near the main cities. Since these are generally along the main stems of major streams or in valleys, a sampling of precipitation on the range watershed areas is not available from their records. Also, there are too few rain gages capable of recording intensities or even individual storm data.

Objectives:

1. To develop and compute parameters that characterize precipitation rates and amounts for application to runoff and erosion predictions.

2. To establish general precipitation-elevation-aspect-slope-relationships from precipitation data obtained in the Reynolds Creek Experimental Watershed for hydrologic and forage production forecasting.

3. To develop depth-duration-frequency and depth-area-duration relationships for the Reynolds Creek Experimental Watershed for application to similar rangeland areas.

4. To formulate and test methods that predict precipitation inputs to hydrologic models for the Reynolds Creek and similar rangeland areas.

PROGRESS

Precipitation data collection was continued in the Reynolds Creek Watershed, comprised of the 49 dual-gage sites (Figure 1). An isohyetal map of average annual precipitation for the years 1968-1974 has been prepared and is shown in Figure 2. Processing for the 1961-1967 precipitation network is progressing. Regression models, stratified by elevation zones and season, will be used to correct precipitation data prior to 1968 from 5-foot unshielded values to actual precipitation.

Completion of processing for the 1961-1967 precipitation network data will provide 15 years of continuing precipitation data for a dense network. The conclusion has been reached that thunderstorm activity is so rare that a dense network can no longer be justified in terms of cost and manpower. The few occurrences that have been observed in the past 15 years have provided data for characterizing thunderstorms on the Reynolds Creek Watershed that will satisfy the needs of Federal, State, and private agencies and groups.

The preponderance of runoff and water yield from the Northwest watersheds, such as Reynolds Creek, comes from snowmelt and long duration, low intensity, winter rainstorms occurring on snow cover and frozen soils. These rainstorms are of wide areal extent so that accurate storm characteristics can be obtained from a relatively sparse network.

To facilitate the network reduction analysis the Reynolds Creek Watershed was divided into five subareas, as shown in Figure 3. These roughly represent Salmon Creek, Macks Creek, Whiskey, Flats-Eastside, and Tollgate. Between-site correlation analysis of daily precipitation amounts was used to assess the spatial variability. Figure 4 shows iso-correlation lines for a key gage in each subarea. Average monthly precipitation was calculated for each subarea as the arithmetic average of all gages within the subarea. Correlation-regression techniques were used to determine the gage site in each subarea, which best described average monthly precipitation. These sites are shown in Figure 5, together with the high and low catch sites. Other factors considered in making the final selection for a 25 dual-gage network were accessibility of sites and proximity to continuing plot or micro-watershed sites. Also, weighing heavily in the selection was that nearly 75 percent of the total water yield for Reynolds Creek Outlet is produced from snowmelt above Tollgate. Also, that Macks and Salmon both measure rest-rotation managed watersheds and are not both needed as intensively gaged watersheds. Figure 6 shows the present 25 dual-gage network sites, together with other active data sites.

A stochastic model, describing annual precipitation variability, was tested, using 13 years (1962-1974) of actual precipitation data at site 023X01. This site effectively represents annual precipitation for the Salmon Creek Watershed. The annual data were first tested for

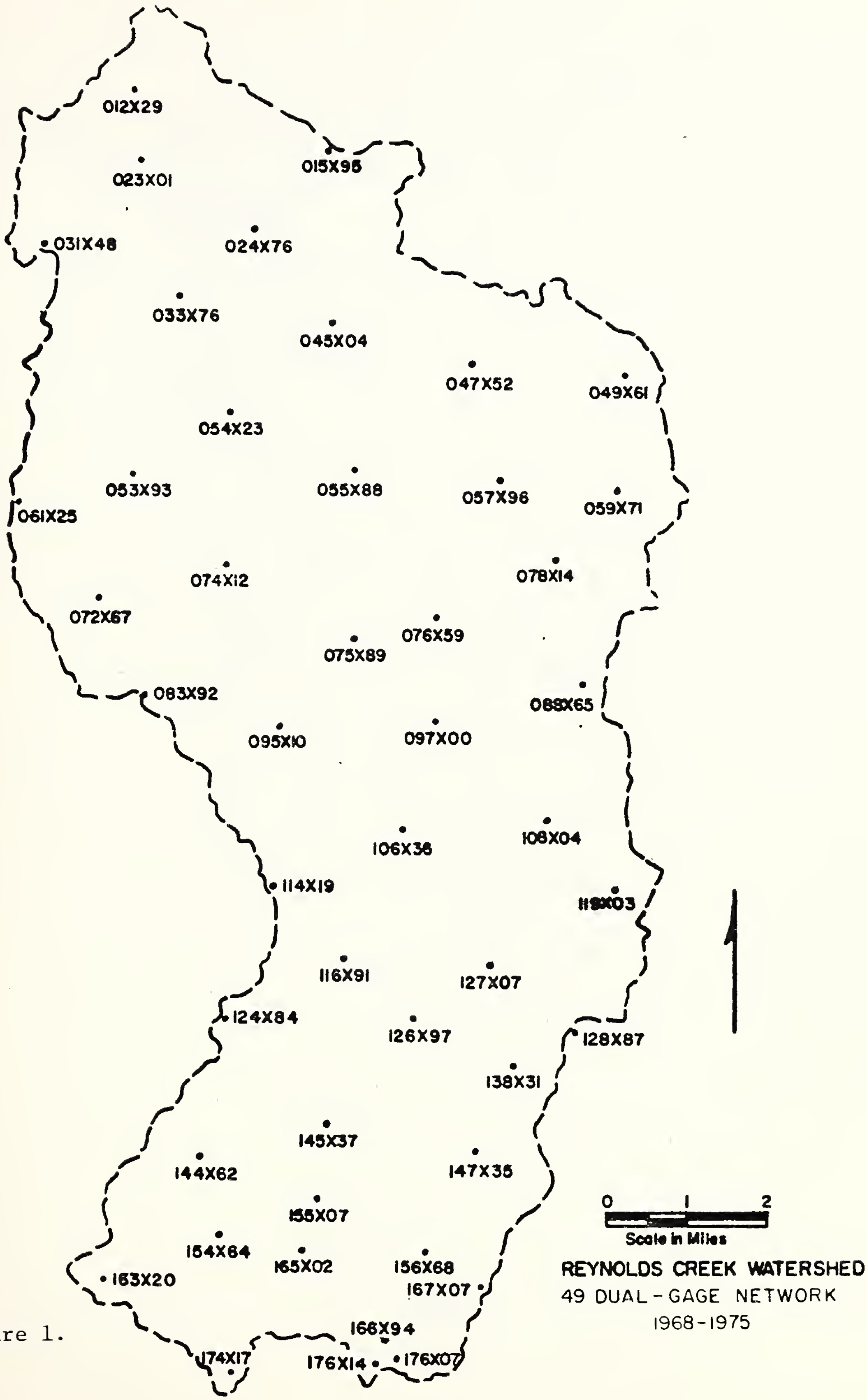
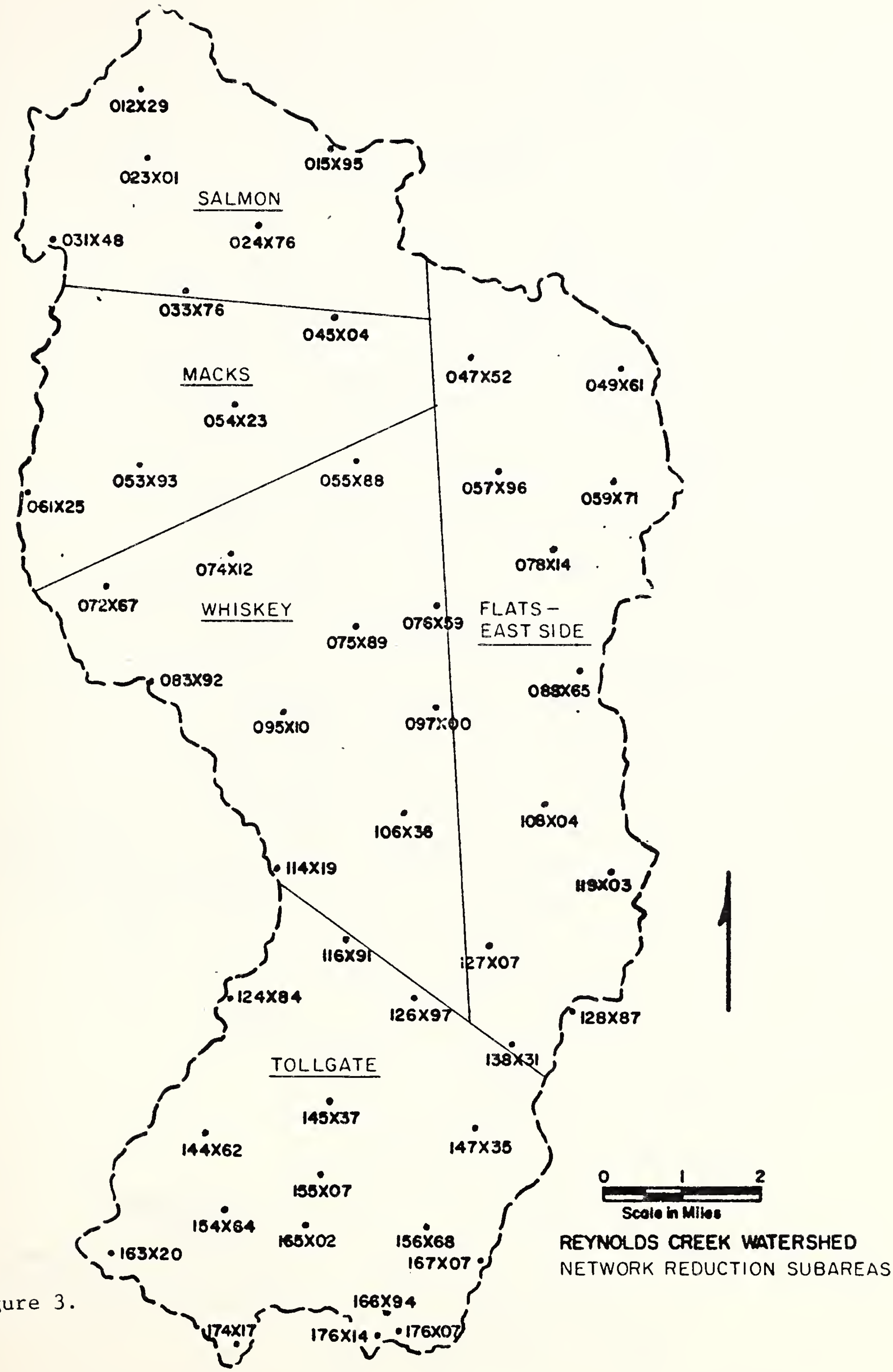

012X29
023X01
015X96
031X48
024X76
033X76
045X04
047X52
049X61
054X23
053X93
055X88
057X96
059X71
061X25
074X12
078X14
072X67
076X59
075X89
083X92
088X65
095X10
097X00
106X38
108X04
114X19
116X91
127X07
124X84
126X97
128X87
138X31
145X37
144X62
147X35
155X07
154X64
165X02
156X68
163X20
167X07
166X94
174X17
176X14
176X07
0
1
2
Scale in Miles
REYNOLDS CREEK WATERSHED
49 DUAL-GAGE NETWORK
1968-1975

Figure 1.


AVERAGE ANNUAL PRECIPITATION (INCHES)
1968-1974
REYNOLDS CREEK WATERSHED
0 1 2
Scale in Miles
RAIN GAGE SITE
20
15
10
20
20
25
25
20
20
25
30
35
40
45
15
20
25
30
35
40
45

Figure 2.



REYNOLDS CREEK WATERSHED
NETWORK REDUCTION SUBAREAS

Figure 3.

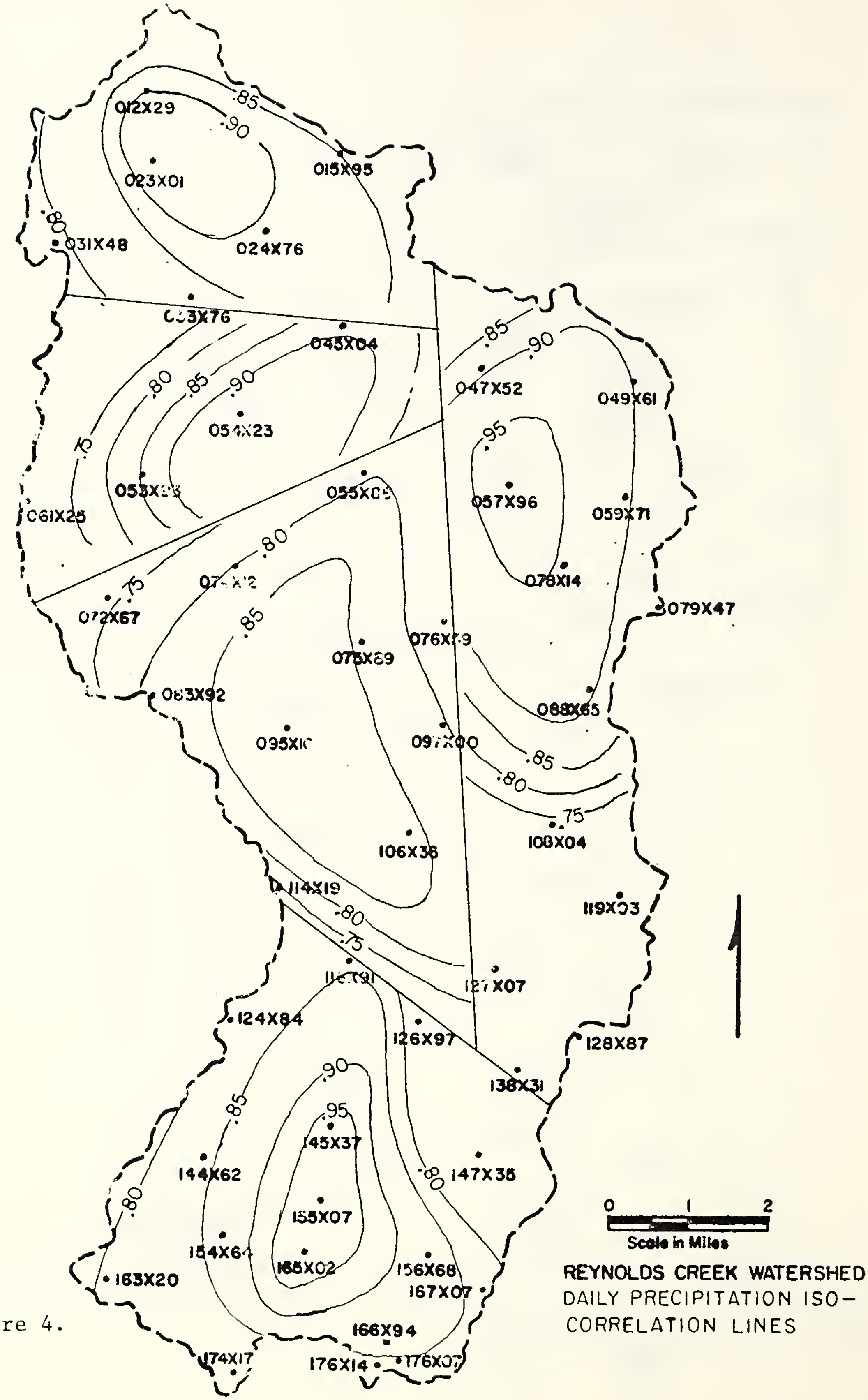

012X29
.85
.90
015X95
023X01
.80
031X48
024X76
045X04
.85
.90
.80
.85
.90
047X52
049X61
054X23
.75
.95
053X
055X
057X96
059X71
061X25
.80
078X14
.75
079X47
072X67
.85
076X
075X
083X92
088X65
095X
097X00
.85
.80
.75
106X36
108X04
114X19
119X
.80
.75
127X07
124X84
126X97
128X87
.90
138X31
.95
.85
145X37
144X62
.80
147X35
.80
155X07
0
1
2
Scale in Miles
154X64
165X02
156X68
163X20
167X07
166X94
174X17
176X14
176X07
REYNOLDS CREEK WATERSHED
DAILY PRECIPITATION ISO-
CORRELATION LINES

Figure 4.

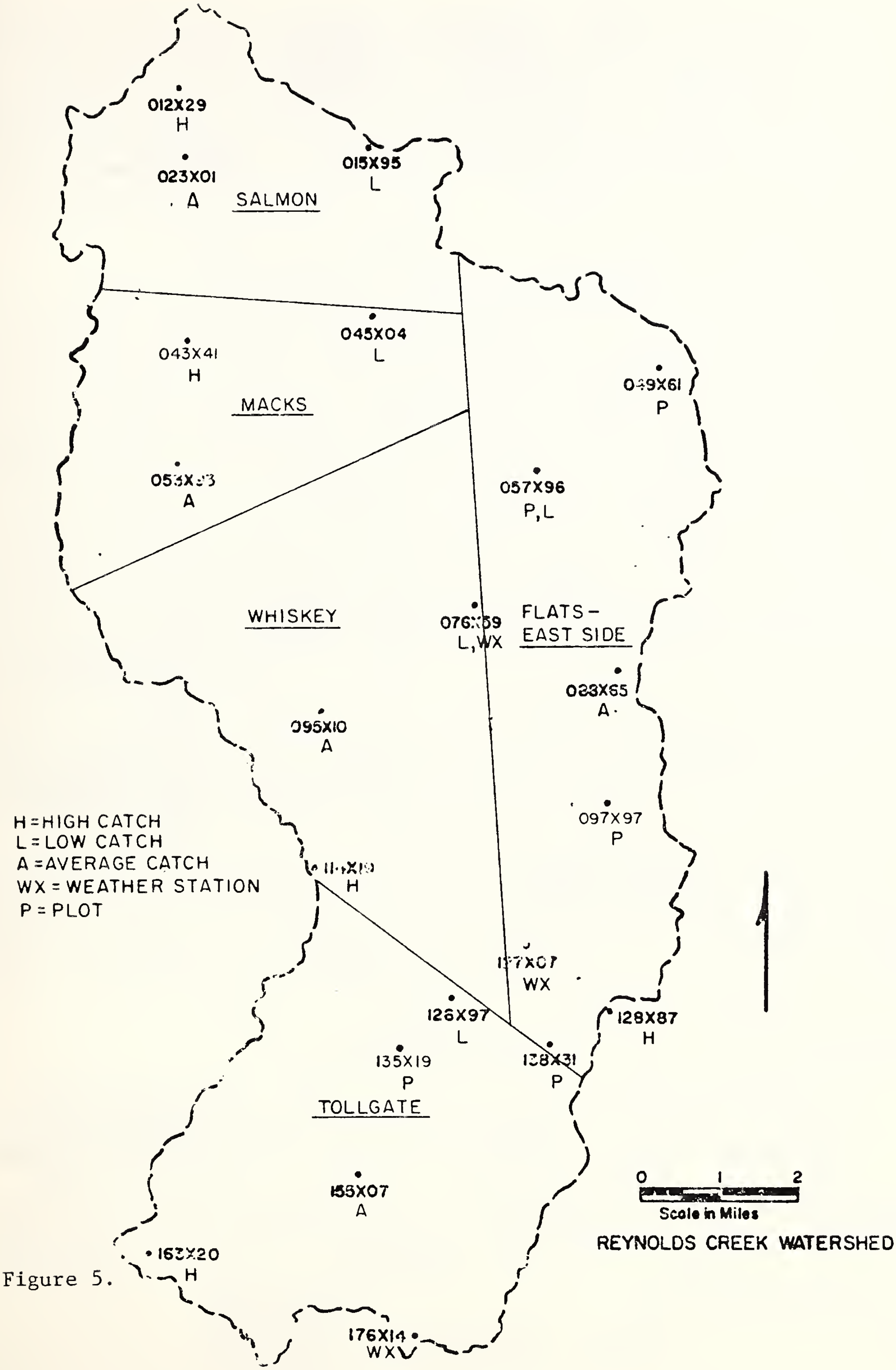

012X29
H
023X01
A
SALMON
015X95
L
045X04
L
043X41
H
MACKS
A
P
057X96
P,L
WHISKEY
L,WX
FLATS-
EAST SIDE
A
095X10
A
097X97
P
H=HIGH CATCH
L=LOW CATCH
A=AVERAGE CATCH
WX = WEATHER STATION
P = PLOT
H
WX
126X97
L
128X87
H
135X19
P
P
TOLLGATE
155X07
A
H
176X14
WX
0
1
2
Scale in Miles
REYNOLDS CREEK WATERSHED

Figure 5.

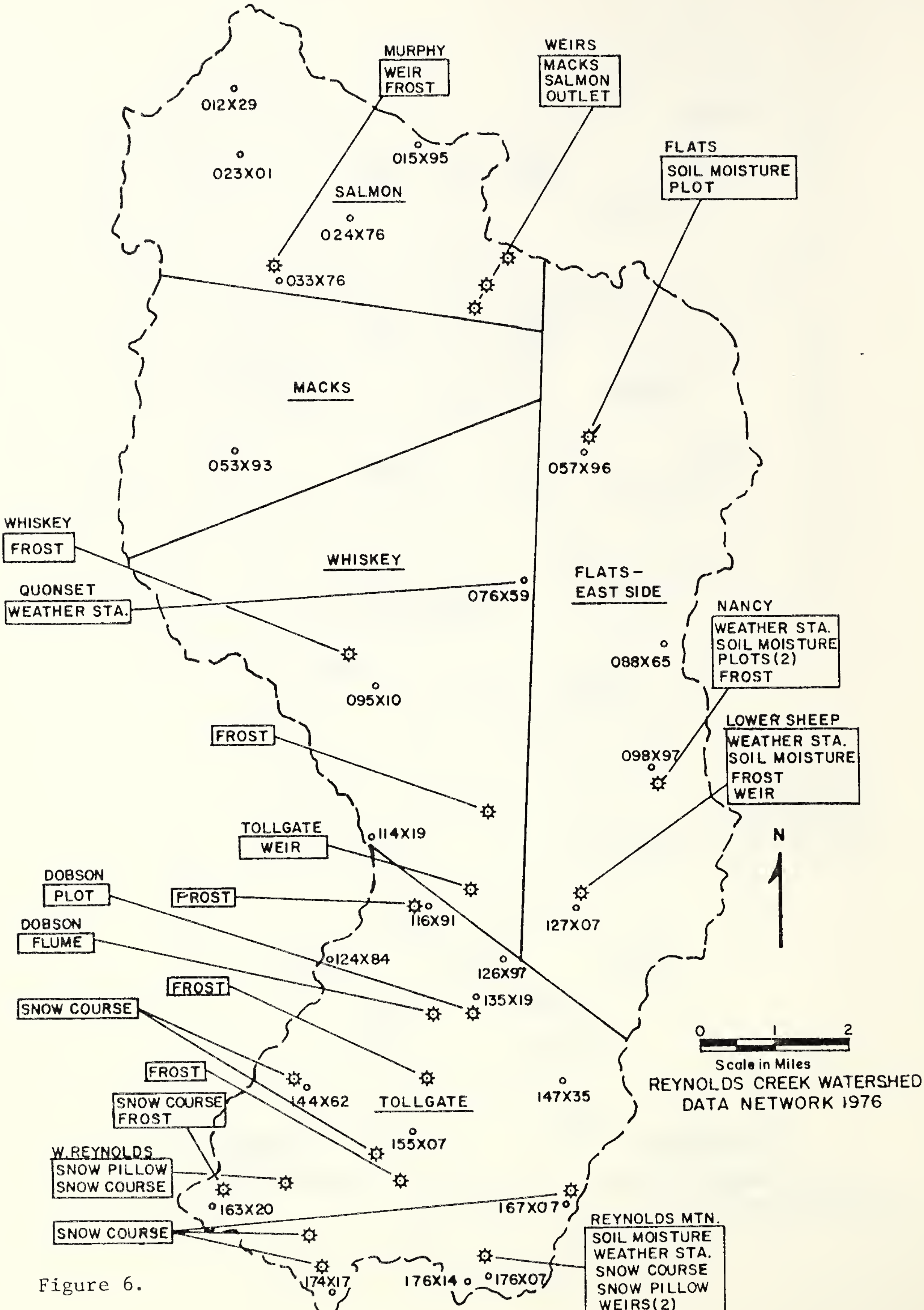

MURPHY
WEIR
FROST
WEIRS
MACKS
SALMON
OUTLET
FLATS
SOIL MOISTURE
PLOT
012X29
023X01
015X95
SALMON
024X76
033X76
MACKS
053X93
057X96
WHISKEY
FROST
WHISKEY
QUONSET
WEATHER STA.
076X59
FLATS-
EAST SIDE
NANCY
WEATHER STA.
SOIL MOISTURE
PLOTS(2)
FROST
088X65
095X10
FROST
LOWER SHEEP
WEATHER STA.
SOIL MOISTURE
FROST
WEIR
098X97
TOLLGATE
WEIR
114X19
N
DOBSON
PLOT
FROST
116X91
127X07
DOBSON
FLUME
124X84
126X97
FROST
135X19
SNOW COURSE
0
1
2
Scale in Miles
REYNOLDS CREEK WATERSHED
DATA NETWORK 1976
FROST
144X62
TOLLGATE
147X35
SNOW COURSE
FROST
155X07
W.REYNOLDS
SNOW PILLOW
SNOW COURSE
163X20
167X07
SNOW COURSE
REYNOLDS MTN.
SOIL MOISTURE
WEATHER STA.
SNOW COURSE
SNOW PILLOW
WEIRS(2)
FROST
174X17
176X14
176X07

Figure 6.

persistence by calculating the autocorrelation coefficient for the data set. The autocorrelation coefficient was not significant, indicating that yearly precipitation is a random value with no evident trend. The historical data were then plotted in several ways and appeared to fit a log-normal probability distribution. The log-normal probability distribution was, therefore, sampled and 100 values of annual precipitation were generated. The model used was:

$$P = \mathrm{EXP}\ (\mu + p\sigma) \tag{1}$$

where P is the generated annual precipitation in inches, μ is the natural logarithm of the mean annual precipitation calculated from the historical data, σ is the standard deviation of the logarithms of the historical data, and p is a random normal number, a large sequence of which has a mean of zero and a standard deviation of one. Excellent agreement between the mean and standard deviation of the historical and generated data were obtained, using this model. In addition, the historical data points appear to fit the generated probability curve quite well. These results are illustrated in Figure 7. While the historical data shows a high of 27.18 inches and a low of 13.36 inches, the generated probability curve allows the estimation of probabilities beyond the range of the historical data, based on the fact that the historical and generated data both have similar statistical characteristics (mean and standard deviation). Figure 5, for example, indicates a 1 percent chance of annual precipitation being less than 12 inches or more than 35 inches.

Additional computer programs have been developed and used to obtain empirical probabilities of daily rainfall amounts at all network sites. These probabilities are essential for the development of stochastic precipitation models of daily and smaller time steps.

The precipitation network established in cooperation with the Idaho Department of Water Resources on the Silver Creek Watershed near Hailey, Idaho was removed on November 15, 1975. Data analysis of the precipitation and snow storage is complete and a final report has been submitted to the Idaho Department of Water Resources.

SIGNIFICANT FINDINGS

The analysis of precipitation data from the 49 site dual-gage network and project objectives and needs indicated that a reduction in network size to a 25 site network could be accomplished.

A stochastic model describing annual precipitation variability was tested. Excellent agreement between the historical and generated data was obtained by sampling the log-normal probability distribution.

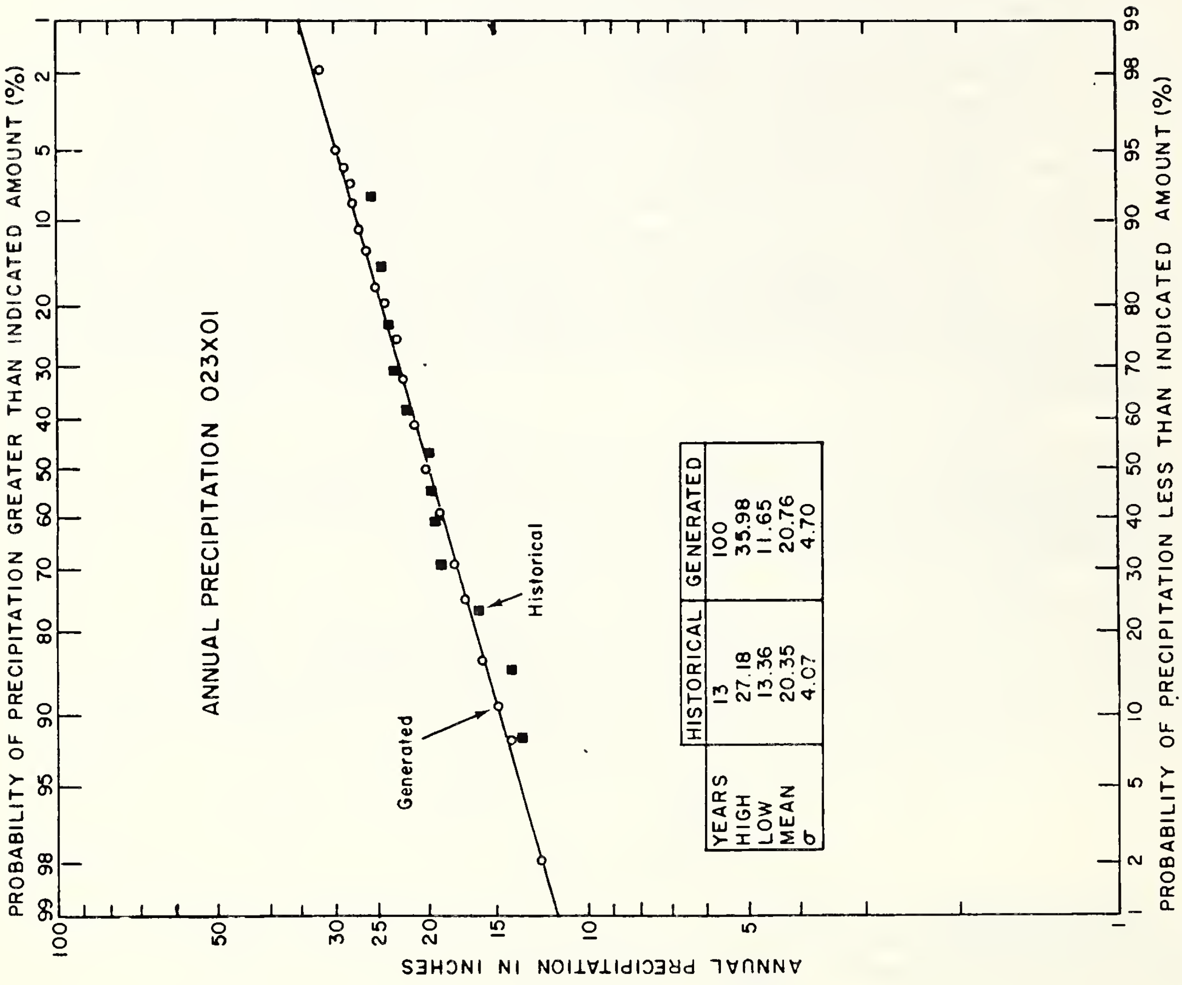

ANNUAL PRECIPITATION 023X01
PROBABILITY OF PRECIPITATION GREATER THAN INDICATED AMOUNT (%)
PROBABILITY OF PRECIPITATION LESS THAN INDICATED AMOUNT (%)
ANNUAL PRECIPITATION IN INCHES
Generated
Historical
	HISTORICAL	GENERATED
YEARS	13	100
HIGH	27.18	35.98
LOW	13.36	11.65
MEAN	20.35	20.76
σ	4.07	4.70

Figure 7.

WORK PLAN FOR FY 77

1. Stochastic models, describing temporal and spatial variations involving daily time steps, will be developed and tested for input to watershed hydrologic models.

2. General precipitation-elevation-aspect-slope-vegetative cover relationships will be investigated for hydrologic and forage production forecasting.

3. Complete processing of 1961-1967 network data.

4. Develop from 15 years of dense network data, precipitation and rainfall inputs required for runoff, erosion predictions.

5. Characterize thunderstorm type precipitation which occurs on Northwest rangeland watersheds.

REPORTS AND PUBLICATIONS

Rawls, W. J., D. C. Robertson, J. F. Zuzel, and W. R. Hamon 1975
Comparison of precipitation gage catches with a modified alter and a rigid alter type windshield. Water Resources Research 11(3): 415-417.

Renard, K. G. and D. L. Brakensiek 1975
Hydrology: State of the Science, Precipitation. Presented at 5th Annual U.S./Australian Range Workshop, Boise, Idaho. To be published as a Water Laboratory Bulletin, Utah State University (in press).

Zuzel, J. F. 1975
Summary report of precipitation and snowmelt data for the Silver Creek-Wood River triangle area in Blaine County, Idaho. Station report.

SNOW

Title: Snow accumulation, snow redistribution, and snowmelt

Personnel Involved:

L. M. Cox, Hydrologist	Supervise the planning, designing, execution, analyzing, and reporting of proposed experiments.
J. F. Zuzel, Hydrologist	Assist in supervising the planning, designing, execution, analyzing, and reporting of proposed experiments.
Michael D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and recording system and radio telemetry systems.
Lee Perkins, Hydrologic Technician	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.
David C. Robertson, Hydrologic Technician	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.

Date of Initiation: 1961

Expected Termination Date: Continuing

INTRODUCTION

Reynolds Creek

A substantial proportion of the runoff from the western rangelands has its origin in rapid melting snow. To improve the quantity or timing of flow from snow-fed streams by manipulation of vegetation or by other practices requires that the behavior of snow be well understood. There has been little research on the behavior of snow in shrub areas--and almost none in the sagebrush areas of the northwest.

Destructive late winter and spring floods in the northwest frequently originate from rapid melting snow at low elevations characteristic of the sagebrush zone. Although there is little likelihood of modifying snowmelt rates enough to alleviate this threat, knowledge about the behavior of snow in the sagebrush zone will be helpful in devising better warning and forecasting techniques that may reduce the danger of life and property from snowmelt floods.

Boise River

Water from snowmelt constitutes over 75 percent of the available supplies in the West. For many years, snow-water equivalent and related hydrometeorological data have been collected manually by the Soil Conservation Service in the Western mountains. These data, as processed and analyzed, have provided water forecasts to a wide range of private, state, and federal water users for management and regulatory purposes. Under the name of "SNOTEL" the Soil Conservation Service is currently involved in upgrading their water supply forecasting program. This involves an upgrading of their hydrometeorological data sensing at snow-course sites, data storage and retrieval systems, and improving their water supply forecasts both in accuracy and in forecast time frame - approaching real time.

There exists a need to accelerate research on solving the problems of sensing snow-water equivalent and related meteorological data at remote mountainous sites, transmitting these data to collection centers, and then verifying for integrity and errors; and, improving water supply forecast models, utilizing hydrometeorological data for making short-term and long-term forecasts.

Objectives:

Reynolds Creek Watershed

1. To determine the physical and meteorological factors contributing to nonuniformity of snow accumulation in shrub-covered study basins on mountainous terrain.

2. To improve snowmelt prediction techniques by evaluating the energy exchange process of the snow surface under different snow cover conditions.

3. To study the oasis effect of isolated, late-lying snowdrifts for potential management that minimizes evaporative losses and maximizes and prolongs water yield from snowmelt.

Boise River Basin

1. To determine which hydrometeorological sensors are best suited for acquiring quality snow-water equivalent and meteorological data from remote mountainous sites during snow accumulation and melt periods in the Boise River Basin.

2. To develop and refine water supply forecasts both in accuracy and in forecast time frame - approaching real time.

PROGRESS ON BOISE RIVER BASIN STUDIES

In cooperation with the Soil Conservation Service, a special snowmelt study was conducted at the Graham Guard Station on the North Fork of the Boise River. The Graham Guard Station site is representative of the early snowmelt component (5600 ft. elevation) that occurs in the Boise River Basin. Daily values of snowmelt, average air temperature, average dewpoint temperature, allwave net radiation, and total wind run were collected for an 8-day period in late April.

During the summer, instrumentation was installed at the Graham site for sensing air temperature, dewpoint temperature, net radiation, wind run, precipitation, and snow-water equivalent changes during the coming winter. The first five parameters are telemetered from this site by a LANDSAT-I data platform. Similar instrumentation is also telemetered by satellite from the Trinity Mountain site that is located at 7880 ft. elevation in the Boise River Basin. Back-up recordings of all these parameters are being recorded by data loggers at both sites. Mores Creek Summit will be the third site for study in the Boise River Basin.

Data collected from these sites is used to establish a data base for evaluating alternative hydromet sensors for obtaining parameters influencing snow-water equivalent accumulation and snowmelt for developing and refining streamflow forecasts on the Boise River during spring snowmelt periods. Streamflow data at two sites are also collected by LANDSAT data platforms by U.S. Geological Survey. This effort is in cooperation with the Idaho Department of Water Resources.

A Water Supply Forecasting Workshop that was jointly organized by the Agricultural Research Service and the Soil Conservation Service was held in Boise on November 4-6, 1975. The purpose of this workshop was to:

1. Review current water supply forecasting techniques,

2. Discuss shortcomings of current methods, and

3. Develop recommendations on how to improve water supply forecasting techniques or develop new techniques.

Participants included representatives from the Corps of Engineers, Bonneville Power Administration, National Weather Service, Bureau of Reclamation, British Columbia Water Resource Service, State of Idaho, Soil Conservation Service, and Agricultural Research Service.

A workshop proceedings is in preparation.

PROGRESS ON REYNOLDS CREEK SNOW STUDIES

Snowmelt model:

Development has begun on a snowmelt model that is applicable to the isolated late-lying snowdrift situation, which is typical of much of the snowmelt runoff in Reynolds Creek. The basic model has been written and calibrated with one year's data. Inputs are net radiation, wind run, average vapor pressure, and average air temperature for daily time periods. The model output is daily melt, evaporation or condensation, along with cumulative values of these daily results. Provisions will be made to input daily precipitation amounts. The model is somewhat restricted in that it is applicable only to the isolated drift case and assumes that the snowpack is isothermal. Ten more days of data were collected in late June and early July from isolated drifts to increase the data base for this model.

Natural vegetation for snow management:

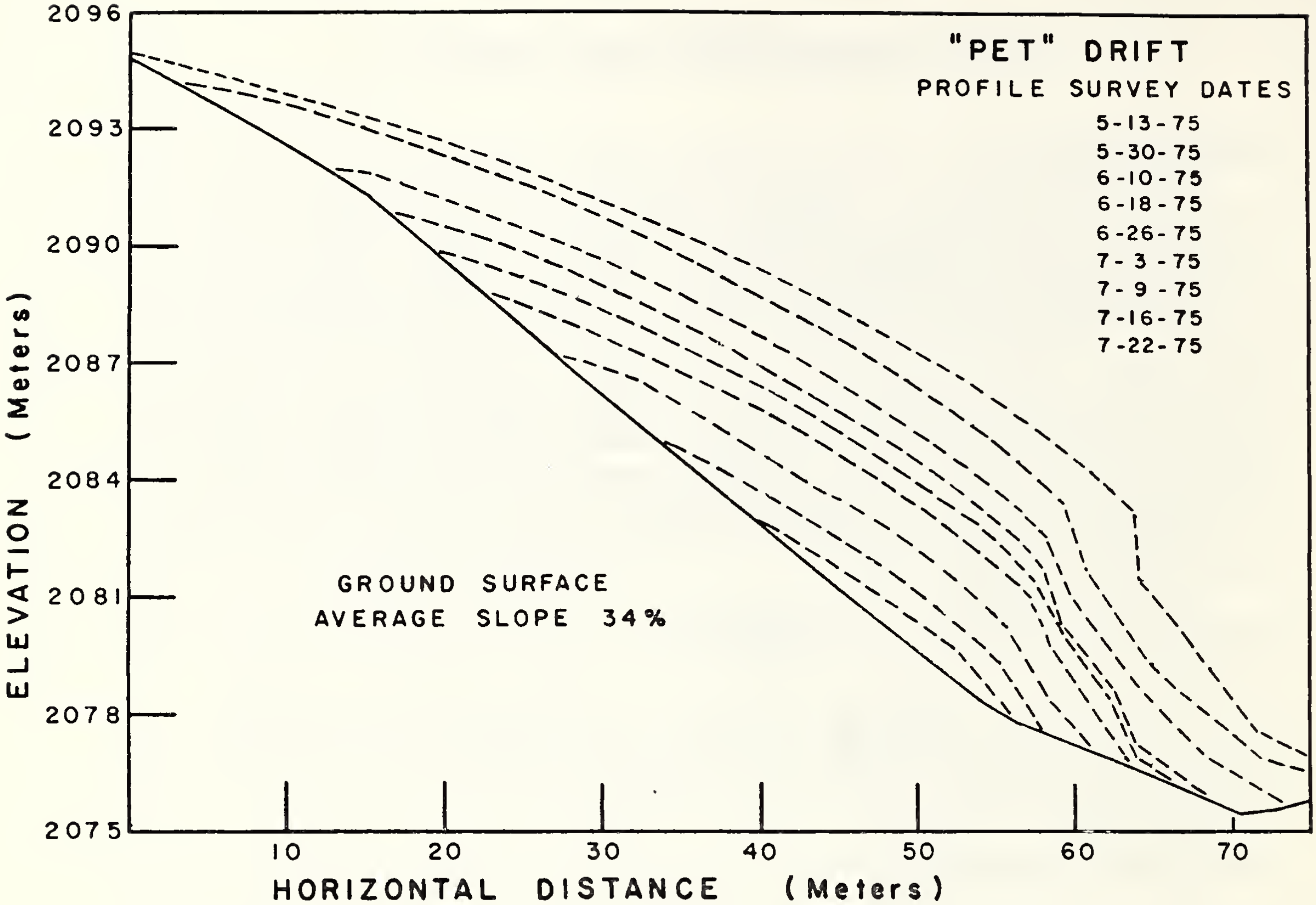
A trial planting of Monterey Knob Cone Pine trees was made in April 1973, to test the possibility of using natural vegetation for snow management purposes. A recent survey indicated that only about one-third of the 200 trees planted have survived.

Snowdrift surface profiles:

Snowdrift surface profiles were made at weekly intervals on the SOCAB and PET drifts during the snowmelt season (Figure 1). These data are used in water balance studies and as independent checks for evaluating the snowmelt model. As can be seen in Figure 1, the shape of the snowdrift surfaces during formation are determined by the slope of the existing ground surface. This surface shape is maintained throughout the ablation period.

Ground surface data for the SOCAB and PET drift sites were used to test Tabler's model (Tabler, 1975) for predicting snowdrift profiles on sagebrush rangeland. The resultant predicted profiles and the 1975 measured profiles are shown in Figure 2. The predicted profiles were based on the assumptions that 12 inches of snow-water equivalent were available for redistribution over a fetch of 2000 feet.

Based on these assumptions, the Tabler model predicted 7 percent more water stored in the PET drift than was actually measured. Predicted values were 15 percent higher for the SOCAB than the measured values. These initial results certainly warrant further investigation and possible modification.



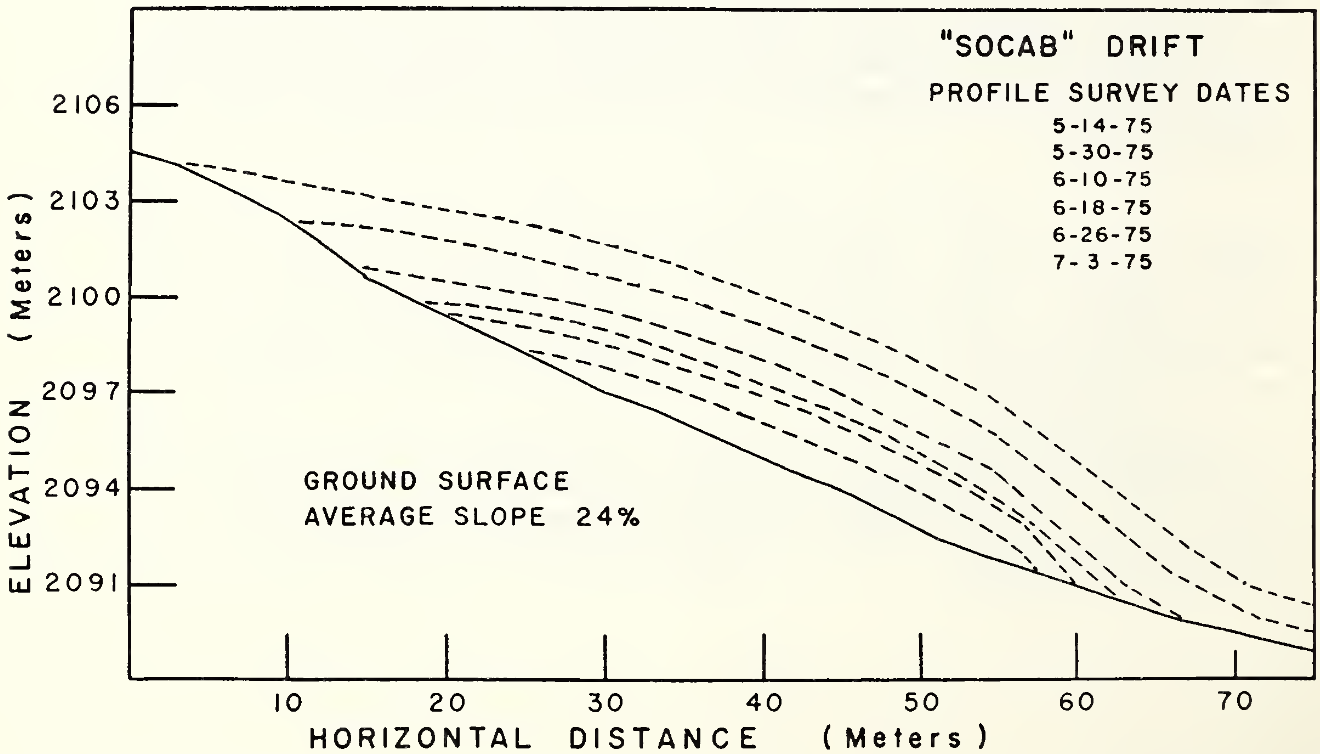
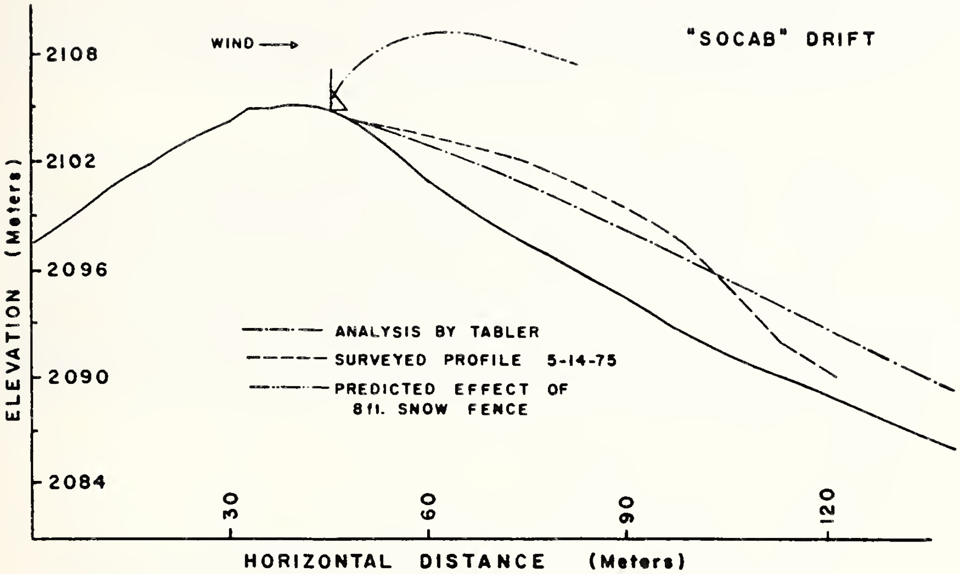


Figure 1. Snow surface profiles for PET and SOCAB snowdrifts during 1975 snowmelt season.



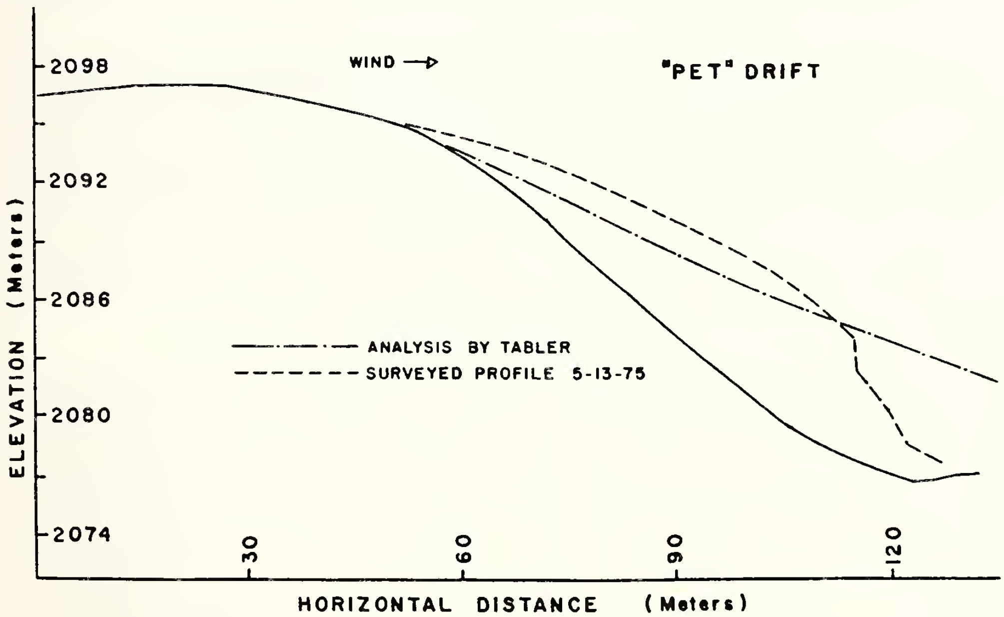


Figure 2. Comparison of predicted and measured snow surface profiles for SOCAB and PET snowdrifts. Upper graph also depicts the predicted surface profile that would result from placing an 8-foot snow fence at the SOCAB drift site.

Rain gage data indicated that 32 inches of snow-water equivalent was recorded in this area during the winter precipitation period. No measurements have been made to determine how much of this total precipitation is available for redistribution. It does appear that a considerable amount of the total snow-water equivalent that is received here is lost either through sublimation or transported to locations that are subjected to early snowmelt periods.

The Tabler model was also used to test the effect of placing an 8-foot drift at the SOCAB site. Results of this study (Upper Graph, Figure 2) indicate that an 8-foot snow fence would reduce the exposed horizontal surface area of the drift by 60 percent. In reducing the surface area there should also be a similar reduction realized in the total daily snowmelt volume from this drift area. By placing snow fences at these drift sites it appears that the period of water yield could be extended. Hopefully, a field evaluation of managing snowdrift accumulation and shape by snow fences will be initiated.

Sensible heat transfer to snow surfaces:

A field method was tested for determining the sensible heat transfer to an isolated late-lying snowdrift. The method consisted of measuring the amount of snowmelt and evaporation that occurred from a shaded snow surface. The snow surface tested was shaded with a pan 1 meter square that was filled with melting snow. Therefore, the radiant heat transfer component was eliminated from the shaded surface. Daily measurements of snowmelt and evaporation of the shaded surface were made by using a core method developed by Cox, 1974.

Results were compared with the Corps of Engineers (1956) and Sverdrup's (1936) methods and are shown in Table 1. In Sverdrup's method the sensible heat is calculated from existing meteorological conditions. The Corps of Engineers method uses an energy balance approach to obtain the sensible heat term.

In all cases but one, Sverdrup's method resulted in the highest values obtained. On the average, it exceeded the Corps of Engineers method by 20 percent and the shading method by 9 percent.

TABLE 1.--Daily sensible heat transfer to a snow surface, as determined by the Corps of Engineers, Sverdrup's, and a shading method.

	Corps of Engineers	Shading	Sverdrup
	LY	LY	LY
	143	152	154
	68	81	115
	64	100	96
	193	200	251
	242	262	264
TOTAL	710	795	880

The shading method does have an advantage in that it is a more direct measure of the actual process. The other two methods require more sophisticated instrumentation. The shading method has the disadvantage in that more snow has to be added to the shade pan about every two hours. The pan also has to be adjusted periodically in order to maintain the test surface in the shade from sunrise to sunset.

SIGNIFICANT FINDINGS

A snowdrift profile prediction model was tested on two drifts, and produced results within 7 and 15 percent of measured values.

A field method was successfully tested for determining sensible heat transfer to a snow surface. This method has the advantage of being a more direct approach to measuring sensible heat input and produced results within 9 percent of other methods currently in use.

WORK PLAN FOR FY 77

Boise River (ARS-SCS)

1. Tabulate streamflow data in Boise River for previous years.

2. Tabulate snow course data for same time period in Boise River Basin.

3. Process Boise River data for FY 77 from LANDSAT-I sites. (Twin Springs and Featherville).

4. Conduct special snowmelt study at Trinity Mountain and Graham Guard Station sites during May-June 1976, for evaluating sensor performance and for developing real-time combination forecast model.

Reynolds Creek (ARS-BLM)

1. Continue snowdrift surface profile study on PET and SOCAB drift sites for refining snowdrift surface profile prediction model.

2. Conduct special snow study on late-season snowdrifts for further enlarging data base for snowdrift snowmelt model.

3. Modify one drift site with snow fencing.

REFERENCES CITED IN TEXT

Cox, L. M. 1974
A new device for evaluating the energy exchange processes that contribute to the ablation of a snowpack. Presented at Pacific Northwest Section American Geophysical Union, Missoula, Mont., American Geophysical Union 55(2): 77.

Sverdrup, H. U. 1936
The eddy conductivity of the air over a smooth snow field - results of the Norwegian - Swedish Spitzbergen Expedition in 1934. Geofysiske Publikasjoner, 11(7): 1-69.

Tabler, Ronald D. 1975
Predicting profiles of snowdrifts in topographic catchments. Proceedings of the 43rd Western Snow Conference, April 23-25, Coronado, Calif., pp. 87-97.

U. S. Army Corps of Engineers 1956
Snow hydrology. Summary Report of the Snow Investigation. North Pacific Division, Corps of Engineers, Portland, Ore., 437 pp.

REPORTS AND PUBLICATIONS

Burgess, M. D. and L. M. Cox
A bipolar analog integrator for use with net radiometer. Accepted for publication in Agricultural Meteorology.

Cox, Lloyd M. 1975
Nature's reservoir ... Summer's water from winter's snow. Agricultural Research 24(3): 4 pp., September.

Cox, L. M., W. J. Rawls, and J. F. Zuzel 1975
Snow: Nature's reservoir. Water Resources Bulletin 11(5): 1009-1012, October.

Cox, L. M. and J. F. Zuzel 1976
A method for determining sensible heat transfer to the snow surface. To be presented at Western Snow Conference, April 20-22, Calgary, Canada.

Cox, L. M., John F. Zuzel and Lee Perkins
A device for evaluating the water vapor exchange between snow and air. Accepted for publication in Water Resources Research.

Robertson, D. C., J. F. Zuzel, and L. M. Cox 1975
Water supply outlook for Reynolds Creek Watershed as of March 14. (Station report).

Zuzel, John F. and Lloyd M. Cox 1975
Relative importance of meteorological variables in snowmelt. Water Resources Research 11(1): 174-176.

Zuzel, John F., David C. Robertson, and Walter J. Rawls 1975
Optimizing long-term streamflow forecasts. Journal Soil and Water Conservation 30(2): 76-78, March-April.

Zuzel, John F. and William T. Ondrechen 1975
Comparing water supply forecasting techniques. Proceedings of Watershed Management Symposium--Irrigation and Drainage Division, ASCE, pp. 327-336, August.

VEGETATION AND SOIL MOISTURE

Title: Evaluation of cover production, herbage yield, and soil conditions for different levels of vegetation management

Personnel Involved:

G. A. Schumaker, Soil Scientist	Plan, design, and coordinate research activities and prepare reports.
C. L. Hanson, Agricultural Engineer	Perform computer analysis relative to soil moisture data and assist in analyzing field data.
D. L. Coon, Hydrologic Technician	Responsible for various aspects of data collection and field observations, including soil moisture measurement and calibration; compile and process data.

Date of Initiation: May 1971

Expected Termination Date: Continuing

INTRODUCTION

Quantitative data on herbage yield from rangelands under different levels of management are needed to guide land managers in coordinated multiple use of the range. These needs require more discerning information on how vegetation and soils respond to imposed treatments, including controlled grazing. Information is also needed with regard to methods of increasing cover and to the rate of recovery of native range following intensive practices.

Objectives:

1. To determine the effects of grazing management and treatments on yield of herbage, cover production, soil moisture regime, and soil surface conditions at selected sites.

2. To study changes in plant density and plant composition as a result of grazing management and treatments.

PROGRESS

For report purposes, the vegetation and soils research progress on the Reynolds Creek Experimental Watershed has been divided into the following subheadings:

A. Brush Treatment Studies
B. Effects of Grazing and Nongrazing Treatments
C. Effects of Intensive Grazing at the Nettleton Site
D. Plant Adaptability Nurseries
E. Soil Surface Factor Observations

A. Brush Treatment Studies:

The study reported here was designed to determine the effects of chemical and mechanical sagebrush control on forage yields at differing annual precipitation zones, compared with adjacent grazed and ungrazed areas without brush control.

The sagebrush-grass region of Idaho currently occupies about 17 million acres and is the largest grazing region in the state (Tisdale, et al., 1969). Several studies indicate that burning, chemical, or mechanical brush control are practices that may be used to reduce sagebrush and increase other forage species in this region (Hyder and Sneva, 1956; Hyder and Sneva, 1962; and Johnson, 1958).

The variation in plant communities and annual precipitation amounts on the Reynolds Creek Experimental Watershed offered an excellent opportunity for studying the effects of grass and forb understory response to sagebrush control. The watershed is located in southwest Idaho (Figure 1). Watershed elevations range from 3900 feet, where the annual precipitation is about 10 inches per year, to over 7000 feet, where the annual precipitation is in excess of 45 inches per year. Big sagebrush (*Artemesia tridentata*) is the dominant plant species on much of the watershed area and, thus, the study area represents a large area of the Snake River Plains and Northern Great Basin (Passey and Hugie, 1962).

Study Areas and Methods

Study Areas

The four study sites shown in Figure 1 range in elevation from 4500 to 6500 feet. While all sites had a dense cover of sagebrush, average annual precipitation varied from 13 inches at Nancys Gulch to 45 inches at Reynolds Mountain. Elevation, precipitation, and other site information is given in Table 1. Drifting snow accumulates at the Sheep Creek and Reynolds Mountain Sites, and thus, there is additional available water for plant use in excess of precipitation. A major portion of the precipitation at these two sites comes in the form of snow. Precipitation at all sites occurs primarily during winter and early spring.

Table 1. Information for four study sites receiving brush treatments in southwestern Idaho (elevation, ft; precipitation, in).

Site	Nancys Gulch	Whiskey Hill	Sheep Creek	Reynolds Mtn.
Elevation	4600	5500	6100	6800
Precipitation	13	23	20 1/	43 1/
Percent Slope	8	15	33	6
Aspect	NE	E	NE	N
Geologic Material	Basalt	Granite	Basalt	Rhyolite
Soil Subgroup	aridic calcic agrixerolls	typic haperdolls	agric cryoborolls	pachic cryoborolls
Soil Family	fine, loamy, mixed, mesic	coarse, loamy, mixed, frigid	fine-loamy, mixed	fine-loamy, mixed
Soil Series	Babbingion loam	Takeuchi rocky coarse sandy loam	Harmehl and Demast loam	Bullery gravelly loam
Type of Chemical Treatment	2,4-D 2/	2,4-D 2/	2,4,5-T	2,4-D 2/
Dosage of Chemical	1½ lb/ac	1½ lb/ac	2½ lb/ac	1½ lb/ac
Date of Initiating Study	May 1971	June 1972	June 1969	June 1971

1/ Receives additional water from drifted snow.
2/ Low volatile ester.

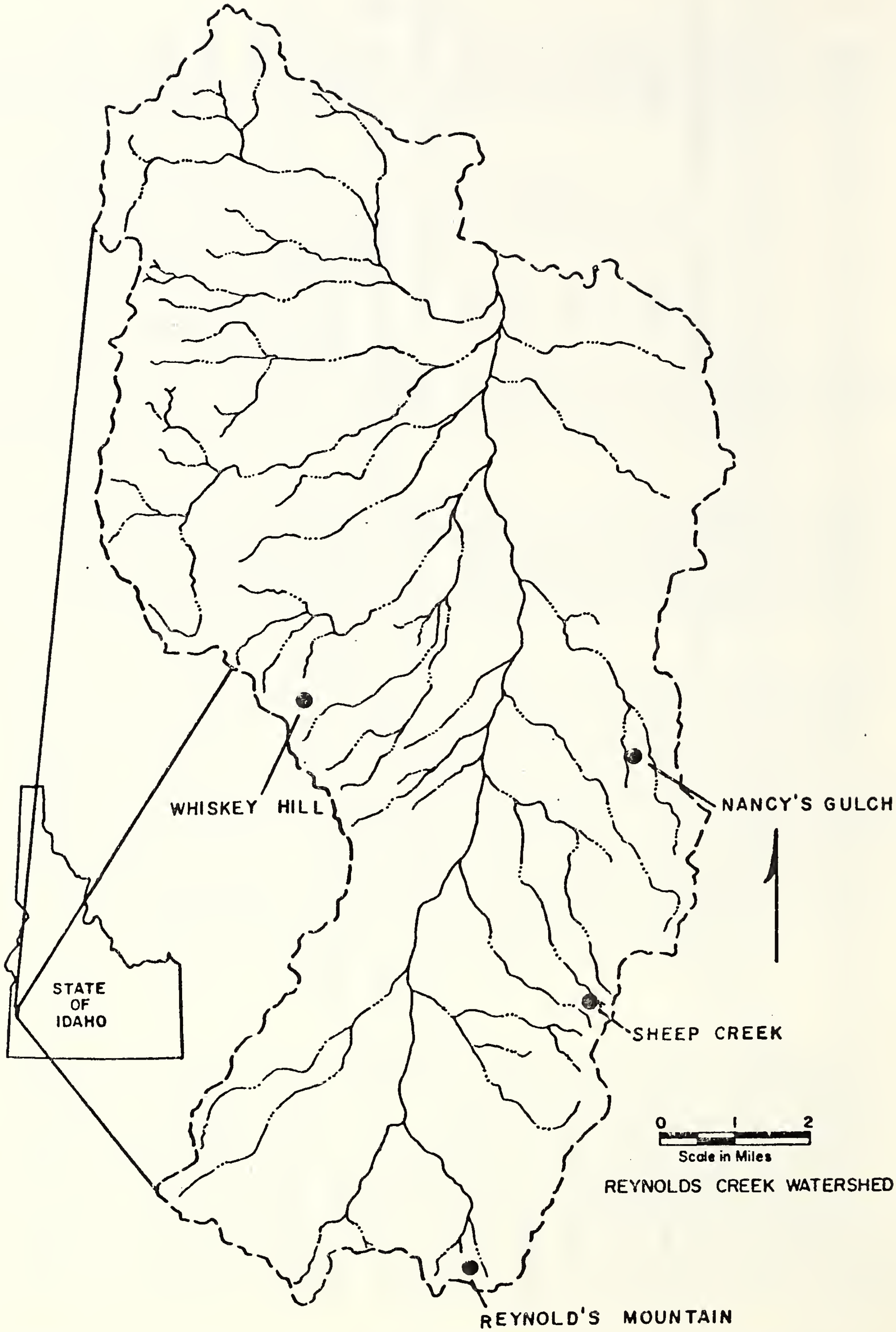


Figure 1. Location of four brush treatment sites on Reynolds Creek Experimental Watershed.

Treatments

Exclosures of approximately one-half acre were fenced before brush treatment. Grazing of surrounding areas continued unchanged. Time of treatment for each site is shown in Table 1. Treatments consisted of mechanical removal of sagebrush, chemical spray, an untreated check, and grazed. The grazed areas under study were adjacent to the exclosure and equal in size to the fenced areas. The number of grazing animals was not controlled, however. Small portable exclosures of 16 feet^2 wire net were used to cover sampling sites prior to grazing each spring. New sampling sites were selected each year. Treatments were the same at each site, except at Whiskey Hill, where mechanical removal of sagebrush was omitted. Mechanical removal consisted of grubbing off all sagebrush plants at ground level. Rates of spray application of either 2,4-D or 2,4,5-T are shown in Table 1. Dosages of 2,4-D were purposely kept low, as recommended by the Bureau of Land Management. Time of spraying coincided with new growth of 3-4 inches (Hyder, et al., 1958), but dosages were lower than those recommended by Cornelius, et al., (1958). Treatments were the same at each site, except at Whiskey Hill, where mechanical removal of sagebrush was omitted.

Sampling

Sampling for herbage yield was undertaken at each site when the major grass species at that site were in head. The primary grass species at the sites are listed in Table 2. The herbaceous portion of the brush species was considered as annual growth and only this portion was included in the samples. Annual herbage production was determined for each treatment by estimating specie weights and by actual weighing, using the double sampling method described by Wilm, et al., (1944). Each year sample plots 9.6 feet^2 were selected at random and individual plant species were clipped and weighed in the field. These samples were then oven dried and weighed again. Green field weights aided in making more precise weight estimates on the estimated plots. Estimated sample weights were expressed as green weight. All samples weights were adjusted to an air dry weight of 12 percent moisture, based on the moisture content of the clipped samples.

Statistical Analysis

Forage yields were analyzed by an analysis of variance. Duncans multiple range test for significance was applied at the 5 percent probability level (LeClerg, 1962).

Table 2. List of primary plant species at four study sites receiving brush treatment.

Nancys Gulch	Whiskey Hill	Sheep Creek	Reynolds Mtn.
Big sagebrush	Big sagebrush	Big sagebrush	Big sagebrush
Artemisia tridentata	*Artemisia tridentata*	*Artemisia tridentata*	*Artemisia tridentata vaseyana*
Sandburg bluegrass	Sandburg bluegrass	Needleandthread grass	Mountain brome
Poa secunda	*Poa secunda*	*Stipa comata*	*Bromus marginatus*
Cheatgrass	Cheatgrass	Pubescent wheatgrass	Sedges
Bromus tectorum	*Bromus tectorum*	*Agropyron trichophorum*	*Carex* sp.
Bearded bluebunch wheatgrass	Idaho fescue	Mountain brome	
Agropyron spicatum	*Festuca idahoensis*	*Bromus marginatus*	
Phlox		Snowberry	
Phlox sp.		*Symphoricarpos oreophilus*	

Results and Discussion

Total Herbage Yield

Total herbage produced was not different among treatments at Nancys Gulch, Whiskey Hill, or Sheep Creek sites, Figures 2, 3, and 4. This indicates that there was a sufficient recovery of the understory vegetation so that the mechanical removal and spray treatment yields were nearly equal to the check and grazed treatments. The average annual yields varied from 693 pounds per acre at Nancys Gulch to 1587 pounds per acre at Sheep Creek. This yield difference is an indication of both precipitation and soil difference. At the Reynolds Mountain site total yields of 900 and 1000 pounds per acre on the sprayed and mechanically treated plots, respectively, were about 400 pounds per acre less than the yields from the untreated (check) and grazed plots, left, Figure 5. Spraying at the optimum time resulted in almost a complete sagebrush kill at Reynolds Mountain, and a dense stand of grasses and forbs were present on the sprayed and mechanical plots during the years after treatment. Total yields varied from year to year, primarily because of variation in spring precipitation. For instance, spring rains provided adequate moisture in 1971 and yields on the spray treatment averaged 3400 pounds per acre while the average was 2650 in 1973 when spring rains were almost nil.

Nonsage Yields

Nancys Gulch. A comparison of nonsage herbage yields at the Nancys site shows that significantly more herbage was produced where sagebrush was mechanically removed, as compared with any of the other treatments, right, Figure 2. The spray treated plot produced nearly 500 pounds per acre of herbage, but this was not significantly greater than the nonsage herbage grown on the untreated (check) and grazed plots. Sagebrush kill at this low moisture site was 65 to 70 percent. It is very likely that conditions for growth following spraying were not favorable, as discussed by Hyder and Sneva (1962). Spray application at the recommended dosage was applied when *Poa secunda* was headed and fading in color. It seems probable that the presence of some sagebrush plants on the sprayed plot did not permit the optimum growth of the understory grasses and forbs.

Whiskey Hill. The 2,4-D treated plot produced 765 pounds per acre, which was significantly more than either the untreated (check) or grazed plots, right, Figure 3. Where animals were withheld from grazing on the check plot, more nonsage plant material was produced than on the plot subjected to grazing.

Sheep Creek. At this site there was a very good sagebrush kill. The yield from the sprayed plot was significantly greater than from the grazed or untreated (check) plots, producing 750 pounds per acre more

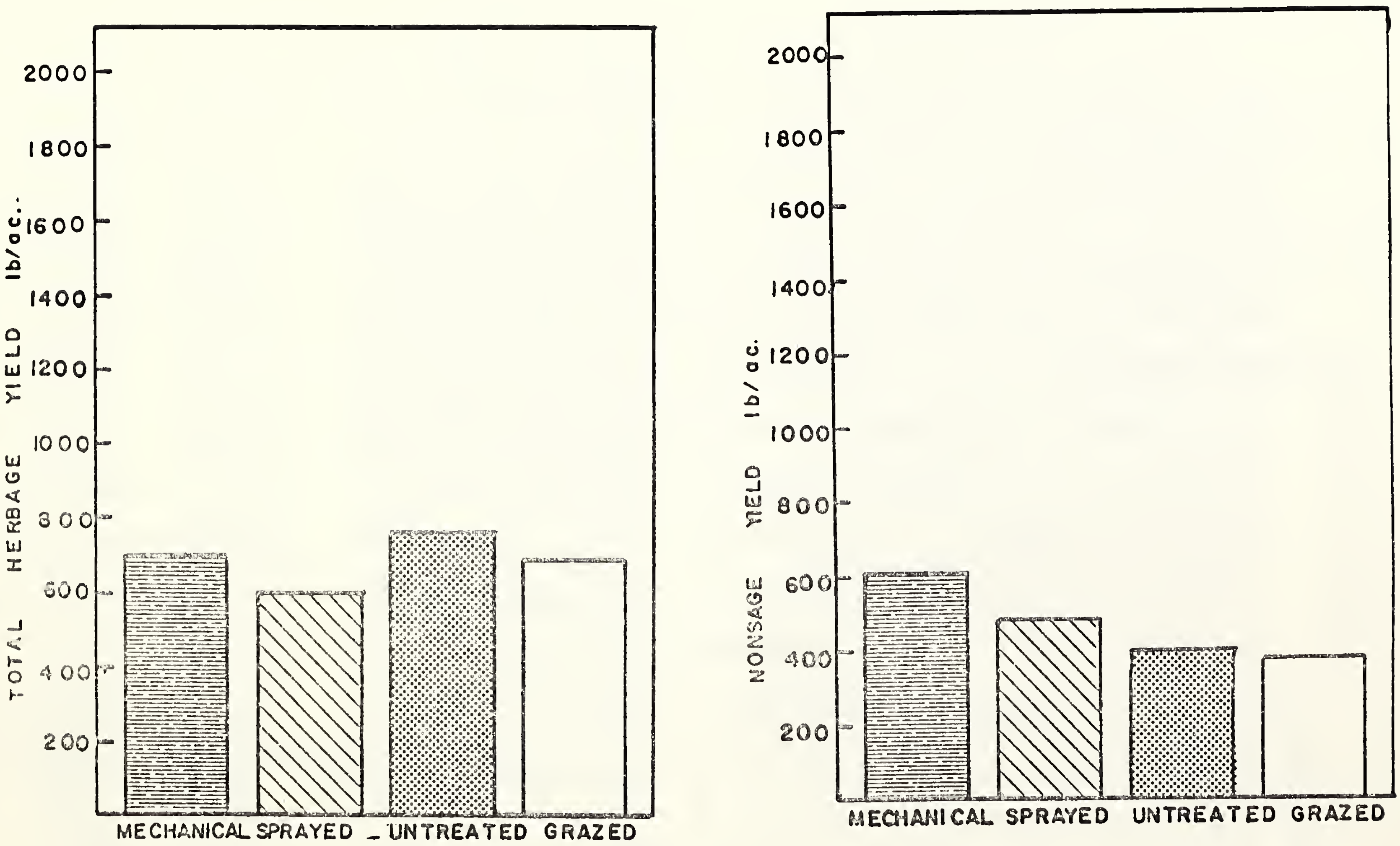


Figure 2. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Nancys Gulch site, 1972-1975 averages.

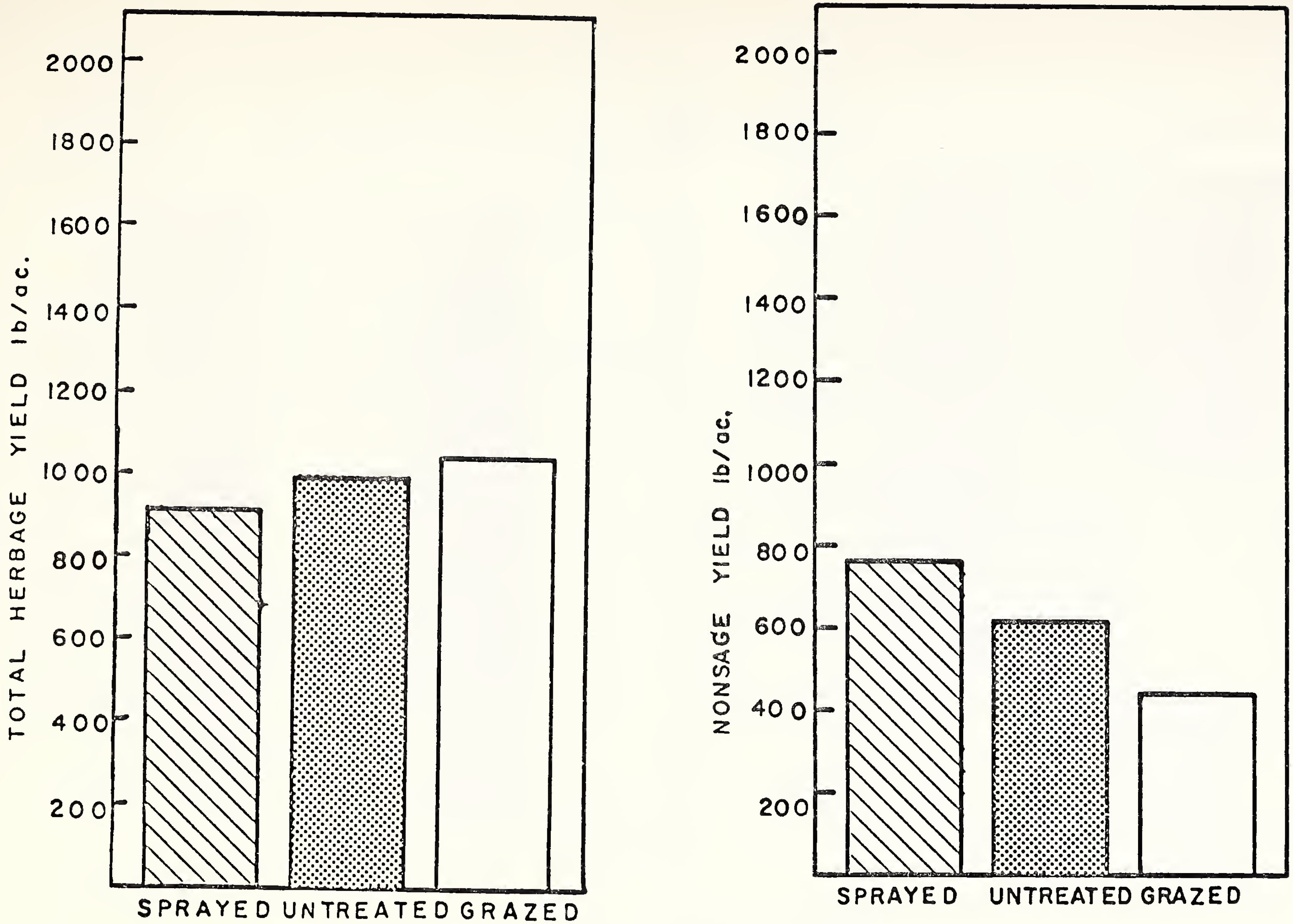


Figure 3. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Whiskey Hill site, 1973-1975 averages.

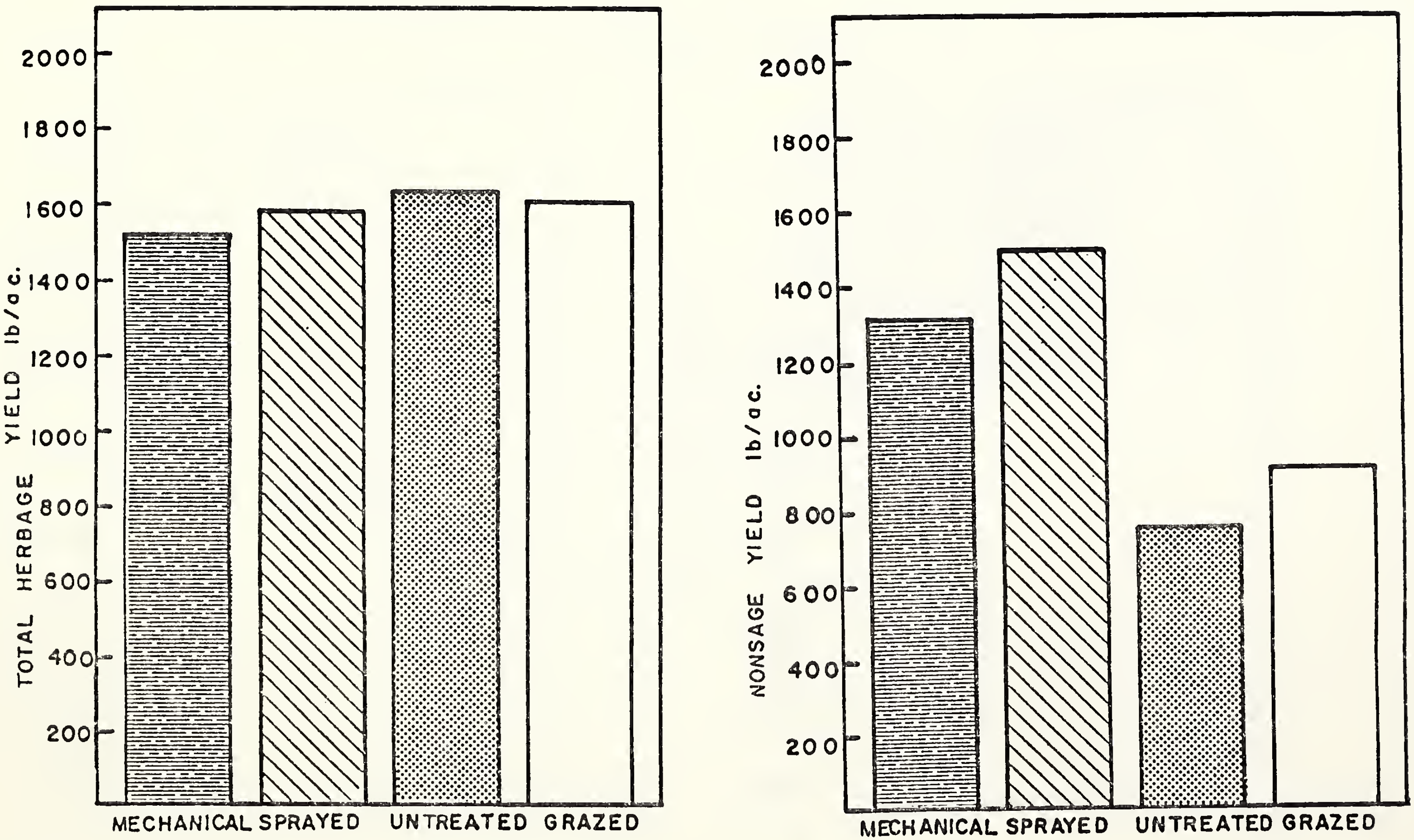


Figure 4. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Upper Sheep Creek site, 1971-1975 averages.

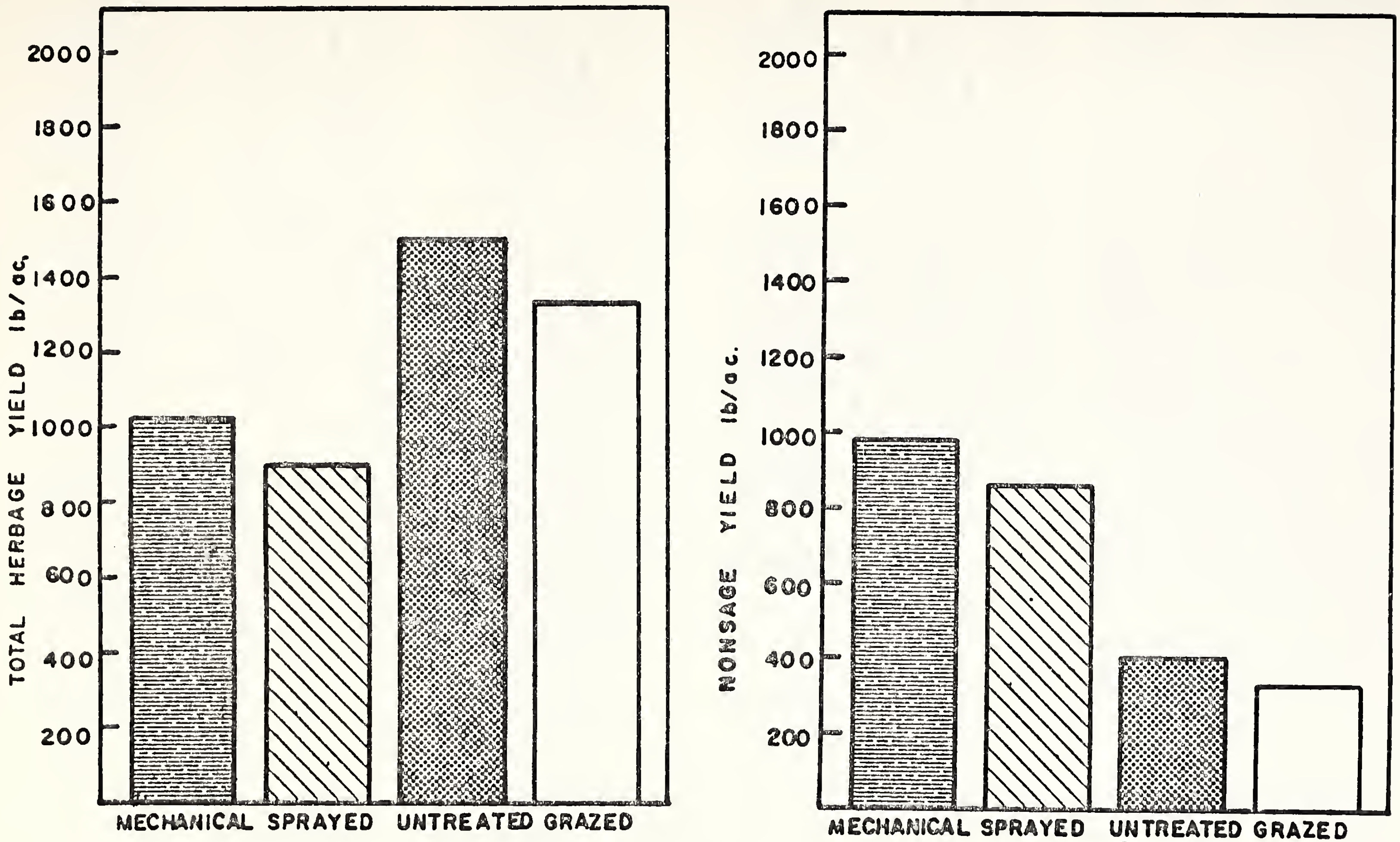


Figure 5. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Reynolds Mountain site, 1972-1975 averages.

of grasses and forbs than the untreated (check), right, Figure 4. While nonsage yields from the mechanical plots were significantly greater than from the check or grazed, the yield was not as high as from the sprayed plot. Some reinvasion of sagebrush was noted after 4 years on the mechanical treatment, and this was probably a contributing factor to an average yield that was 200 pounds lower than that produced on the sprayed plot. The grazed treatment produced about 150 pounds per acre more nonsage plant material than the untreated check and was significantly different at the 5 percent level. It is noteworthy that at the Sheep Creek site abundant grass was produced in the mid-summer with good seed production from the grasses. Robertson (1947) reports similar observations following spraying.

Reynolds Mountain. Yield of the nonsage portion of the plant material from both the mechanical removal and sprayed plots were similar and were significantly greater than yields from either the untreated (check) and grazed plots, right, Figure 5. While soils are relatively deep, snow is slow to leave the Reynolds Mountain site at the 6500-foot elevation, and this may account for the lower production than at the Sheep Creek site. The mechanical removal plot had an abundance of lupine, which was nearly 26 percent of the total herbage production. Lupine was also present on the other treatments, but represented no more than 2 percent of the total production. Spraying probably reduced the presence of lupine on the spray plots, and the dense sagebrush cover kept it at a low level.

Plant Composition

The change in plant composition, from the time of imposing the treatments on through the years the study was conducted, is of interest. Long-term results of Harniss and Murray (1973) show that sagebrush yields had increased over the years following brush treatment, while grass and forb yields decreased. Plant species yield data are grouped as grasses, forbs, or sagebrush and are expressed as percentage of the total yield for each treatment in Figure 6.

Nancys Gulch. Sagebrush composition remained at a low level on the mechanical treatment during the course of the study. Twenty percent sagebrush, or more, was present on the sprayed plot from 1972 through 1975, indicating an imcomplete kill. The size of sample at Nancys was smaller in 1971 than other years, giving rise to a larger sampling error. Therefore, the percent sagebrush after spraying was probably greater than 10 percent.

Whiskey Hill. Spray was applied in 1972, but the effect of the kill was not fully evident until 1973. There is no distinct trend in composition on the check plot during the period of study. On the grazed plot the sagebrush composition remained high while the grass and forb composition was low during the period of study.

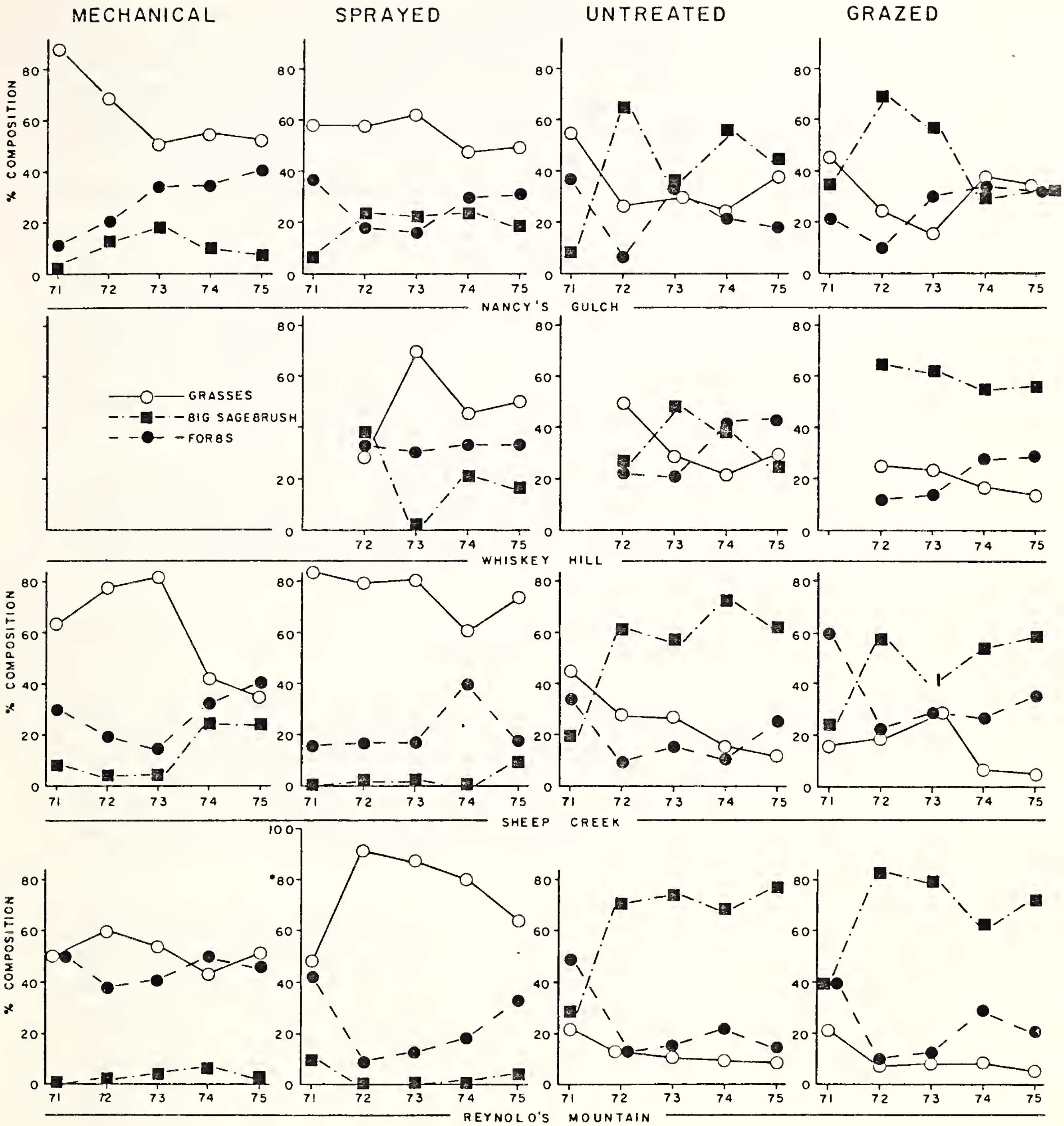


Figure 6. Plant composition at brush treatment sites on Reynolds Creek Experimental Watershed from 1971-1975.

Sheep Creek. Spraying was implemented in 1969; however, data for plant composition was not available until 1971. Sagebrush composition was low on the mechanical removal plot until 1974 when young seedling plants began to increase in size. Cook and Lewis found more than 70 percent of the reinvading sagebrush to be present 2 years after brush removal. Grass composition increased through 1973 and then declined, with an increase in both forbs and sagebrush. Grass and forb composition on the untreated (check) and grazed plots was relatively low from 1974 through 1975.

Reynolds Mountain. Composition remained fairly stable on the mechanical treatment during the period of study. The kill from spraying was slow to take effect and some sagebrush was measured on the sprayed plot in 1971, but was almost nil after that. The understory grasses increased dramatically in 1972, but dropped off during the remaining years of the study as forb composition increased. Sage composition remained high on the check and grazed plots during the period of study.

There was an absence of young seedling plants on the sprayed plots during the period of study. Observations of Johnson (1958) indicate that on areas protected from grazing the number of young sagebrush plants were minimal. The long-term effects of sagebrush eradication are not available; however, about 15 years can be anticipated before respraying is necessary (Kearl, 1965).

Summary and Conclusions

Mechanical treatment of sagebrush allowed understory grasses and forbs to produce abundant forage at all sites investigated, but the greatest response, when compared to the check, was at sites receiving higher amounts of precipitation. Chemical treatment of sagebrush produced significantly greater yields of nonsage plant material at three of the sites. Competition from the sagebrush remaining alive contributed to the low nonsage yields at the drier Nancys Gulch site.

Mechanical removal of sagebrush permitted a large increase in the grass composition; however, grass composition showed a decline at two of the sites a few years after treatment because of sagebrush regrowth. Sagebrush seedlings increased in size during the period of study at Sheep Creek and accounted for 20 percent of the plant composition at the end of the study. Use of chemicals to kill sagebrush caused a distinct change in plant composition, with grass making up the major portion of the forage at all the sites studied.

REFERENCES CITED IN TEXT

Blaisdell, James P. 1949
Competition between sagebrush seedlings and seeded grasses. Ecology 30: 512-519.

Cook, C. Wayne and Clifford E. Lewis 1963
Competition between big sagebrush and seeded grasses on foothill ranges in Utah. Journal of Range Management 16(5): 245-250.

Cornelius, Donald R. and Charles A. Graham 1958
Sagebrush control with 2,4-D. Journal of Range Management 11(3): 122-125.

Harniss, Roy O. and Robert B. Murray 1973
Thirty years of vegetal change following burning of sagebrush-grass range. Journal of Range Management 26(5): 322-325.

Hyder, Donald N. and Forrest Sneva 1956
Herbage response to sagebrush spraying. Journal of Range Management 9(1): 34-38.

Hyder, Donald N. and Forrest Sneva 1962
Selective control of big sagebrush associated with bitterbrush. Journal of Range Management 15: 211-219.

Hyder, D. N., F. A. Sneva, D. G. Chilcote, and W. R. Furtick 1958
Chemical control of rabbitbrush with emphasis upon simultaneous control of big sagebrush. Weeds 6(3): 289-297.

Johnson, W. M. 1958
Reinvasion of big sagebrush following chemical control. Journal of Range Management 11(4): 169-172.

Kearl, W. Gordon 1965
A survey of big sagebrush control in Wyoming 1952-1964. Univ. of Wyoming Agri. Exp. Sta. Mimeo. Circ. 217, November.

LeClerg, Erwin L., Warren H. Leonard, and Andrew G. Clark 1962
Field plot technique. Burgess Publ. Co., Minneapolis, Minn.

Passey, H. B. and V. K. Hugie 1962
Sagebrush on relict ranges in the Snake River Plains and Northern Great Basin. Journal of Range Management 15: 273-278.

Robertson, Joseph H. 1947
Responses of range grasses to different intensities of competition with sagebrush (*Artemisia tridentata*). Ecology 28: 1-16.

Tisdale, E. W., M. Hironaka, and M. A. Fosberg 1969
The sagebrush region in Idaho, a problem in range resource management. Idaho Agri. Exp. Sta. Bull. 512, 15 pp.

Wilm, H. G., David F. Costello, and G. E. Klippe 1944
Estimating forage yield by the double sampling method. Journal American Society of Agronomy 36(3): 194-203.

Figure Titles

Figure 1. Location of four brush treatment sites on Reynolds Creek Experimental Watershed.

Figure 2. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Nancys Gulch site; 1972-1975 averages.

Figure 3. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Whiskey Hill site; 1973-1975 averages.

Figure 4. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Upper Sheep Creek site; 1971-1975 averages.

Figure 5. Total herbage yield (left) and nonsage yield (right) for different brush treatments at the Reynolds Mountain site; 1972-1975 averages.

Figure 6. Plant composition at brush treatment sites on Reynolds Creek Experimental Watershed from 1971-1975.

B. Effects of Grazing and Nongrazing Treatments:

Yield and basal cover data were analyzed from sites on the watershed having grazed and nongrazed treatments. Six years have lapsed since exclosures were installed at the study sites. Data for the fifth and sixth years were analyzed, comparing yield and transect data. Data from both sparse and dense sites were compared, since sites with both types of cover had grazed and nongrazed treatments. Statistical analysis of total yield, including sagebrush and nonsage yields, showed no significant difference between treatments at any of the sites, Table 3.

The Upper Sheep Creek sparse vegetation site was the only location where the basal cover on the nongrazed and grazed treatments were significantly different. At this location there was more basal cover on the nongrazed treatment. More basal hits from the area where animals had not grazed for 5 and 6 years did not result in more total herbage yield.

Based on these data and observations, the effect of withholding grazing animals for a 6-year period has not increased the basal cover or the herbage yield.

TABLE 3.--Yield of total annual growth and basal hits out of 100 points; 1974 and 1975 averages.

	Yield (pounds/acre)		Basal Hits	
	Ungrazed	Grazed	Ungrazed	Grazed
Flats (Sparse)	576	590	17	16
Lower Sheep (Sparse)	589	685	21	22
Upper Sheep (Sparse)	428	450	16 1/	10 1/
Reynolds Mountain (Sparse)	651	685	20	21
Nancys Gulch (Dense)	815	650	21	26
Upper Sheep Creek (Dense)	1432	1438	23	19
Reynolds Mountain East (Dense)	1468	1376	21	20

1/ Means were significantly different at the .95 level using the t test.

C. Effects of Intensive Grazing at the Nettleton Site:

Cattle were turned into the grazed portion of the Nettleton study, beginning on May 28, and were taken out 18 days later. Temperatures were cooler than normal during April and May and soil moisture was adequate. There was good grass growth by late May when Sandberg bluegrass was starting to head. Total yields from the grazed and nongrazed treatments were 638 and 1322 pounds per acre, while nonsage yields were 356 and 1190 pounds per acre, respectively. The effects of heavy grazing at this site for the period of study were beginning to show and forage produced on the grazed treatment was half that from where animals had not grazed since 1970.

The 6.33 acres under grazing provided 2250 pounds of feed. The usual requirement for an animal is 750 pounds of feed for a 30-day period. Therefore, if it is assumed that an animal would require 450 pounds of forage for 18 days then the eight head using the area would require 3600 pounds. This indicates that the forage produced was not sufficient to meet animal requirements and that the area would have been subjected to severe grazing.

There were 23 basal cover hits per 100 points for the grazed treatment and 45 for the nongrazed treatment. The nongrazed area also had considerable litter with very little exposed bare ground.

D. Plant Adaptability Nurseries:

Species adaptation trial plantings were established at three locations on the Reynolds Creek Experimental Watershed during the fall of 1974. The complete list of entries was given in the 1974 annual report. This work is being conducted in cooperation with the Intermountain Forest and Range Experiment Station, U. S. Forest Service, Boise, Idaho. They also provided technical help in evaluating the plantings during the 1975 growing season.

At the Flats site, which is relatively dry and receives about 10 inches of precipitation annually, nine grasses and five shrubs showed some promise and are listed in Table 4. Russian wildrye (*Elymus junceus*) and Siberian wheatgrass (*Agropyron sibiricum*) showed the most promise among the seeded grasses. The intermediate wheatgrass (*Agropyron intermedium*) varieties also looked good. Tegmar, a drought resistant, lower growing form, appeared somewhat better than other collections. The dryland orchardgrasses did not do well at this site. A dense stand of mountain rye (*Secale montanum*) did not develop, but the vigor and growth rate of those plants which did become established were considered very good, and 20 percent of the established mountain rye plants produced viable seed the first year. Various hybrids of *Agropyron* did not do well on this site.

TABLE 4.--Promising species at the Lake Bed Flats site.

Symbol	Scientific Name	Common Name	Source
AGTR[2] B2-68	*Agropyron trichophorum*	Stiffhair Wheatgrass	Idaho (Topar)
AGIN B13-70	*A. intermedium*	Intermediate Wheatgrass	Comm. (Tegmar)
AGIN B4-68	*A. intermedium*	Intermediate Wheatgrass	Wyoming (Oahe)
AGIN B6-68	*A. intermedium*	Intermediate Wheatgrass	Comm. (Amur)
AGCR X	*A. cristatum*	Fairway Wheatgrass	Logan (ARS)
AGDE B1-68	X *A. desertorum*	X Crested Wheatgrass	
AGDE B2-68	*A. desertorum*	Crested Wheatgrass	Montana (Nordan)
AGSI B1-68	*A. sibiricum*	Siberian Wheatgrass	Idaho
ELJU B9-61	*Elymus junceus*	Russian Wildrye	Tetonia, Idaho
Forbs			
Shrubs			
ATCA B13-65	*Atriplex canescens*	Fourwing Saltbush	Ephraim, Utah
EPNE B3-71	*Ephedra nevadensis*	Nevada Ephedra	Pine Valley, Utah
EPVI B7-69	*E. viridis*	Green Ephedra	Manti, Utah
EULA B1-73	*Ceratoides lanata*	Winterfat	Hatch, Utah
EULA B5-74	*C. lanata*	Winterfat	Reynolds Creek, Idaho

Performance of the forbs at the Flats was very poor. Some stands may have been lost due to freezing weather after early spring germination.

Shrubs at the Flats site were weak; however, several species do show some promise and are reported in Table 4.

Those species which showed the most promise at the Nancy site are listed in Table 5. This site receives about 13 inches of precipitation annually.

Mountain rye (*Secale montanum*) is among the more promising grasses at this site which showed good emergence and appeared robust the first year. The Yugoslavian selection of orchardgrass was superior to any of the other dryland forms planted. This is the B24-65 *Dactylis glomerata* selection. All selections of intermediate wheatgrass (*Agropyron intermedium*) looked good. Among the *Agropyron* hybrids received from Logan, Utah the *Agropyron cristatum* x *Agropyron desertorum* cross was the only one which could be rated fair.

Table 5 also lists the promising forbs at the Nancy site. Good stands of alfalfa (*Medicago sativa*) were obtained. Ladak was slightly better than the other varieties tested. Lewis flax (*Linum lewisii*), a drought tolerant species, appeared to be exceptionally well adapted.

Among the shrubs at the Nancy site, Utah serviceberry (*Amelauchier utahensis*) and bitterbrush (*Purshia tridentata*) were the most promising. Rodents were active at this site, and seeds of the shrubs were eaten by these agents.

In general, there was good germination of nearly all entries at the Reynolds Mountain site. Those selections that showed good vigor and uniformity during the growing season are listed in Table 6. Moisture was very favorable at this site, as the area receives an average of 43 inches annually. The collection of smooth brome (*Bromus inermis*) produced good forage the first year. The Yugoslavian selection of dryland orchardgrass, B16-68 (*Dactylis glomerata*), appeared to be the most productive of the orchardgrass selections at this site. Several *Agropyron* crosses were planted at this site. The *Agropyron repens* x *Agropyron desertorum* planting showed good uniformity and vigor.

Among the forbs at the Reynolds Mountain site, Utah sweetvetch (*Hedysarum boreale utahensis*) did very well. While it is not a native to this area, it appears to be adaptable. Gophers damaged the alfalfa (*Medicago sativa*) plots after excellent emergence was obtained. Rambler looked like the best source.

There was 90 percent or better establishment of all shrubs. Good emergence was reported for mountain snowberry. The mountain mahogany (*Cercocarpos montanus*) selection obtained from the Reynolds area had germinated better than any other source tested. The seedlings that emerged on this site went into the fall season with good vigor.

Evaluation of the nurseries will continue in the 1976 season.

TABLE 5.--Promising species at the Nancy Creek site.

Symbol	Scientific Name	Common Name	Source
Grasses			
AGDE B2-68	*Agropyron desertorum*	Crested Wheatgrass	Montana (Nordan)
AGCR X AGDE B1-68	*A. cristatum* X *A. desertorum*	Fairway X Crested Wheatgrass	Logan (ARS)
AGIN B5-68	*A. intermedium*	Intermediate Wheatgrass	Washington (Greenah)
AGIN B6-68	*A. intermedium*	Intermediate Wheatgrass	Comm. (Amur)
AGIN B13-70	*A. intermedium*	Intermediate Wheatgrass	Comm. (Tegmar)
AGSI B1-68	*A. sibiricum*	Siberian Wheatgrass	Idaho
AGTR[2] B2-68	*A. trichophorum*	Stiffhair Wheatgrass	Idaho (Topar)
BRIN B19-74	*Bromus inermis*	Smooth Brome	GBRS (Northern)
PHPR B7-74	*Phleum pratense*	Timothy	Missouri
SEMO B5-62	*Secale montanum*	Mountain Rye	Turkey PI 274912
Forbs			
COVA B4-60	*Coronilla varia*	Crownvetch	Nebraska (Pingift)
HEBOU B6-69	*Hedysarum boreale utahensis*	Utah Sweetvetch	Orem, Utah
LILE B3-70	*Linum lewisii*	Lewis Flax	Snow College Farm, Utah
MEOF B1-69	*Melilotus officinalis*	Yellow Sweetclover	Montana
MESA B11-69	*Medicago sativa*	Alfalfa	Idaho (Ladak)
Shrubs			
AMAL B10-74	*Amelanchier alnifolia*	Saskatoon Serviceberry	Bonneville Co., Idaho
COMES B3-70	*Cowania mexicana stansburiana*	Stansbury Cliffrose	American Fork, Utah
PUTR B5-72	*Purshia tridentata*	Antelope Bitterbrush	Boise, Idaho
PUTR B36-73	*P. tridentata*	Antelope Bitterbrush	Washoe Co., Nevada

TABLE 6.--Promising species at the Reynolds Mountain site.

Symbol	Scientific Name	Common Name	Source
Grasses			
AGCR X AGDE B1-68	*Agropyron cristatum* X *A. desertorum*	Fairway X Crested Wheatgrass	Logan (ARS)
AGDA X AGCA B1-69	*A. dasystachyum* X *A. caespitosum*	Thickspike X Caespitosum Wheatgrass	Logan (ARS)
AGDE B2-68	*A. desertorum*	Crested Wheatgrass	Montana (Nordan)
AGEL B5-69	*A. elmeri*	Wheatgrass	Commercial
AGIN B4-68	*A. intermedium*	Intermediate Wheatgrass	Wyoming (Oahe)
AGIN B5-68	*A. intermedium*	Intermediate Wheatgrass	Washington (Greenah)
AGIN B6-68	*A. intermedium*	Intermediate Wheatgrass	Comm. (Amur)
AGIN B13-70	*A. intermedium*	Intermediate Wheatgrass	Comm. (Tegmar)
AGJU B3-74	*A. junceum*	Wheatgrass	France PI 276566
AGRE X AGDE B1-70	*A. repens* X *A. desertorum*	Quackgrass X Crested Wheatgrass	Logan (ARS)
AGRI B1-69	*A. riparium*	Streambank Wheatgrass	Comm. (Sodar)
AGSI B1-68	*A. sibiricum*	Siberian Wheatgrass	Idaho
AGTR[2] B3-68	*A. trichophorum*	Stiffhair Wheatgrass	Idaho (Topar)
ALPR B4-69	*Alopecurus pratensis*	Meadow Foxtail	Commercial
BRBI B1-66	*Bromus biebersteinii*	Brome	Aberdeen (SCS)
BRIN B6-74	*Bromus inermis*	Smooth Brome	USSR PI 315374
BRIN B7-74	*B. inermis*	Smooth Brome	USSR PI 315378
BRIN B19-74	*B. inermis*	Smooth	GBRS (Northern)
BRIN B9-69	*B. inermis*	Smooth Brome	Comm. (Lincoln)
CAEP B2-68	*Calamagrostis epigeios*	Chee Reedgrass	Commercial
DAGL B16-68	*Dactylis glomerata*	Orchardgrass	Yugoslavia PI 251112
DAGL B17-65	*D. glomerata*	Orchardgrass	Ephraim (Dryland form)
DAGLH B2-74	*D. glomerata*	Orchardgrass	Australia PI 209888
FEAR[3] B3-68	*Festuca arundinacea*	Reed Fescue	Comm. (Fawn)
PHPR B7-74	*Phleum pratense*	Timothy	Missouri

Table 6.--Continued on next page

TABLE 6.--Promising species at the Reynolds Mountain site continued.

Symbol	Scientific Name	Common Name	Source
Forbs			
ACMIL B8-74	*Achillea millefolium lanulosa*	Western Yarrow	Reynolds Creek, Idaho
BAMA B1-69	*Balsamorhiza macrophylla*	Cutleaf Balsamroot	Cache Co., Utah
COVA B3-67	*Coronilla varia*	Crownvetch	Nebraska (Pingift)
COVA B4-67	*C. varia*	Crownvetch	Comm. (Emerald)
ERUM B5-74	*Eriogonum umbellatum*	Sulfur Eriogonum	Grimes Creek, Idaho
HEBOU B6-69	*Hedysarum boreale utahensis*	Utah Sweetvetch	Orem, Utah
LOCO[3] B5-68	*Lotus corniculatus*	Birdsfoot Deervetch	Vermont (Broadleaf)
LOCO[3] B6-68	*L. corniculatus*	Birdsfoot Deervetch	California (Narrowleaf)
LOCO[3] B7-68	*Lotus corniculatus*	Birdsfoot Deervetch	Canada (Empire)
LOCO[3] B8-59	*L. corniculatus*	Birdsfoot Deervetch	Iowa
MEFA B2-67	*Medicago falcatus*	Sickle Alfalfa	Pullman, Washington
MESA B11-69	*Medicago sativa*	Alfalfa	Idaho (Ladak)
MESA B13-70	*M. sativa*	Alfalfa	Comm. (Rambler)
MESA B32-66	*M. sativa*	Alfalfa	South Dakota
SAMI B10-70	*Sanguisorba minor*	Small Burnet	Comm. - Oregon
Shrubs			
AMAL B10-74	*Amelanchier alnifolia*	Saskatoon Serviceberry	Bonneville Co., Idaho
ARTRV B3-74	*Artemesia tridentata vaseyana*	Sagebrush	Reynolds Creek, Idaho
COMES B3-70	*Cowania mexicana stansburiana*	Stansbury Cliffrose	American Fork, Utah
COMES B6-69	*C. mexicana stansburiana*	Stansbury Cliffrose	Pioche, Nevada
PUTR B1-69	*Purshia tridentata*	Antelope Bitterbrush	Moffet Co., Colorado
PUTR B5-72	*P. tridentata*	Antelope Bitterbrush	Boise, Idaho
ROWO B17-74	*Rosa woodsii*	Woods Rose	Reynolds Creek, Idaho

E. Soil Surface Factor Observations:

Soil surface factor observations were taken at study sites on the watershed after storms of varying intensity occurred on July 20 and July 21, 1975. Some study sites received small amounts of precipitation, while greater amounts at a high intensity caused overland flow at others. Soil surface factor ratings and July 20 and 21 precipitation and intensities for the study sites are shown in Table 7. At the Nancys Gulch site there was some visual evidence of overland flow. The erosion condition for the different treatments was ranked as slight except for the brush removal treatment, which was stable. There was also overland flow at the Whiskey Hill site, and litter and soil movement was evident. The grazed treatment was designated as showing moderate erosion, and the sprayed and untreated plots were very close to the moderate erosion designation. Reynolds Mountain received .60 inch, but the storm intensity did not produce overland flow at the study site.

TABLE 7.--Soil surface factor ratings at study sites for erosion condition class including 1974 readings.1/

Site	Treatment								Storm of July 21, 1975	
	Grazed		Ungrazed		Sprayed		Brush Removal		Precipitation	Intensity In./Hr. for 15 min. interval
	1975	1974	1975	1974	1975	1974	1975	1974		
Flats (Sparse)	11	20	6	17	--	--	--	--	.48	1.92
Lower Sheep (Sparse)	18	21	12	25	--	--	--	--	.08	--
Upper Sheep (Sparse)	24	37	20	34	--	--	--	--	.16	--
Reynolds Mountain West (Sparse)	18	18	14	20	--	--	--	--	.60	1.50
Nancys Gulch	29	27	22	22	23	19	18	21	.60	--2/
Whiskey Hill	49	15	39	4	39	3	--	--	.90	3.20
Nettletons	15	17	1	13	--	--	--	--	.10	--

1/ Erosion Condition Class: Stable 0-20; Slight 21-40; Moderate 41-60; Critical 61-80; Severe 81-100.

2/ Rain fall intensity was not available.

SIGNIFICANT FINDINGS

Brush control studies on four sites at the Reynolds Creek Experimental Watershed showed a significant increase in nonsage herbage yield after mechanically removing sagebrush, when compared to the check. Chemical treatment of sagebrush resulted in a significant increase in nonsage yield over the check or no treatment at three of the four sites under investigation.

Chemical treatment of big sagebrush offers control for a longer period of time than mechanical removal of brush. Seedlings of sagebrush began to appear 4 years after mechanical treatment, while no reinvasion was apparent for as long as 6 years following chemical treatment.

Withholding cattle from grazing at seven sites with both sparse and dense cover for a period of 7 years resulted in no improvement in total herbage produced, when compared with adjacent areas open to grazing. Basal cover also showed no improvement by withholding grazing at six of the seven sites studied.

Secale (*Secale montanum*), a dryland form of orchardgrass, and intermediate wheatgrass selections show promise on the 13-inch precipitation site. A wide selection of grasses, forbs, and shrubs show promise at the 43-inch precipitation site at Reynolds Mountain.

WORK PLAN FOR FY 77

1. Measurement of changes in species composition, cover, herbage yield, and soil surface condition will be continued.

2. Basal area measurements on sparse vegetation micro plots will be undertaken.

3. Water use measurement under different types of brush control will be continued.

4. Dormant season cover measurements will be continued at study sites.

5. Collect data on the adaptability of various species of grasses, forbs, and shrubs.

REPORTS AND PUBLICATIONS

Schumaker, Gilbert A. and Clayton L. Hanson 1976
Herbage response after mechanical and chemical treatment of big sagebrush in southwest Idaho. Prepared for publication in Journal of Range Management.

Hanson, Clayton L., Gilbert A. Schumaker, and Carl J. Erickson 1976
Influence of fertilization and supplemental runoff water on production and nitrogen content of western wheatgrass and smooth brome. Accepted for publication in Journal of Range Management.

EVAPOTRANSPIRATION

Title: Natural evaporation from sagebrush rangelands, alfalfa, and stockponds in a semiarid environment

Personnel Involved:

C. L. Hanson, Agricultural Engineer	Plan programs and procedures; design and construct facilities for evaporation studies. Perform analyses and summarize results.
Michael D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and recording system.
Delbert L. Coon, Hydrologic Technician	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.

Date of Initiation: November 1968

Expected Termination Date: Continuing

INTRODUCTION

The evaporative process under semiarid rangeland is not completely understood for developing predictive relationships. The evapotranspiration component for soil vegetation complexes must be understood so that changes in levels of rangeland management can be hydrologically evaluated. The Northwest Watershed Research Center is conducting evapotranspiration studies designed for measuring and predicting evapotranspiration under sparse vegetative cover and unsaturated surfaces.

Objectives:

1. To measure the evaporative loss of water from sagebrush rangelands, irrigated alfalfa, and stockponds, and observe pertinent meteorological parameters and the soil moisture status.

2. To develop, for predictive purposes, relationships for associating the evaporative loss with meteorological parameters, type and degree of surface cover, soil moisture, and potential evaporative demand.

PROGRESS

The primary emphasis has been in hydrologic modeling. The USDAHL-74 Revised Model of Watershed Hydrology (Holtan, Stiltner, Henson, and Lopez, 1975) is being tested on the 205-acre Summit Basin. The ET routine in this model requires average weekly air temperature and average weekly class A pan evaporation. Air temperatures were obtained from local data, but pan evaporation had to be estimated from a pan at Parma, Idaho. The pan evaporation data available was only for the summer months, so winter pan evaporation had to be estimated from temperature data. This requirement for average weekly class A pan evaporation limits the usefulness of the model because of the few class A pan reporting stations, and there is no winter data at all.

The preliminary information obtained from the model indicates that the model does not evaporate enough water during the cool or cold months and then evaporates excessive water during the early, warm period of the year. This may be because the model was originally written for agricultural crop areas where they do not have winter growth and have most, or at least a considerable part, of the annual precipitation during the growing season. Some, or all, of the vegetation species on the Summit Basin grow any time there is water available and the daytime temperature is warm enough for growth. This growth pattern is not characterized by using mean weekly temperatures and average weekly class A pan evaporation.

At the present time each of the parameters in the ET routine is being evaluated to determine how each affects water use. Then some of the parameters will be adjusted to better fit the actual water use pattern.

The model requires daily class A pan evaporation which was not available for the period being studied. An equation was developed from daily (March 14 through October 14) 1974 class A pan data that may be used during the spring and summer to estimate the daily pan evaporation required in the model. The correlation coefficient was 0.92 and the standard deviation was 0.05, indicating that the equation fits the data very well. This pan is located at the field headquarters on the watershed. The following equation is now being tested on 1975 data:

$$EV = R\,(-0.44 + 0.174T) + .0003W \qquad (1)$$

where:

EV = daily class A pan evaporation (inches/day)
R = daily solar radiation (inches/day)
T = mean daily temperature (^{o}F)
W = 30-foot tower wind run (miles/day)

Two lysimeters at the Lower Sheep Creek Experimental Site were in operation from mid-June through mid-September, 1975. The daily evapotranspiration from these lysimeters was about .08 inch per day in late June and early July, decreasing to .02 inch per day in September. The two lysimeters at the Reynolds Mountain site were instrumented for continuous recording in 1975; however, a lightning storm shortly after the recorder was started ruined some of the equipment and no data were obtained. The four lysimeters will be in operation during the 1976 growing season.

Weekly neutron soil water measurements were obtained in the lysimeters during the growing season. These soil water data are now being processed along with the other biweekly watershed soil water data.

Leaf area index (LAI) was measured periodically on the four lysimeters with the results listed in Tables 1 and 2. LAI on the two Lower Sheep lysimeters reached a maximum of about 1.0 and 0.8 during late June and then decreased through early September. Grass and forb LAI was highest in late May and early June; whereas, the highest sagebrush LAI was in late June. These LAI values are higher than those obtained in 1974.

LAI values on the Reynolds Mountain lysimeters were about 1.0 or higher from late June through late July. They decreased to 0.61 by mid-August and then increased to about 0.8 by mid-September. The higher LAI on the south lysimeter is primarily due to more sage. LAI at Reynolds Mountain was also higher in 1975 than 1974. The Hanson ET model, which requires LAI information, will be used to describe daily ET rates from the lysimeters.

SIGNIFICANT FINDINGS

The preliminary information obtained from the USDAHL-74 Revised Model of Watershed Hydrology indicates that the model does not evaporate enough water during the cool or cold months and then evaporates excessive water during the early, warm part of the year. Parameter adjustment may improve this problem.

WORK PLAN FOR FY 77

1. Continue testing and developing the ET routine in the USDAHL-74 Revised Model of Watershed Hydrology for application to Northwest rangeland watersheds.

TABLE 1.--Leaf area index (LAI) on the lysimeters at Lower Sheep Creek study areas, 1975.

Date	4/24	5/13	6/3	6/16	7/3	7/25	8/13	9/4
Vegetation								
				East Lysimeter				
Grasses	.28	.39	.35	.19	.18	0	0	0
Forbs	.03	.07	.12	.05	.07	0	0	0
Sagebrush	.15	.23	.43	.73	.81	.42	.37	.21
TOTAL	.46	.69	.90	.97	1.06	.42	.37	.21
				West Lysimeter				
Grasses	.27	.35	.24	.09	.10	0	0	0
Forbs	.03	.01	.07	.10	.05	.01	0	0
Sagebrush	.15	.25	.49	.64	.50	.30	.39	.25
TOTAL	.45	.61	.80	.83	.65	.31	.39	.25

TABLE 2.--Leaf area index (LAI) on the lysimeters at the Reynolds Mountain study site, 1975

Date	6/27	7/10	7/22	8/13	9/12	6/27	7/10	7/22	8/13	9/12
	North Lysimeter					South Lysimeter				
Vegetation										
Grasses	.39	.29	.31	.21	.29	.40	.21	.31	.16	.28
Forbs	.15	.20	.16	.04	.02	.23	.15	.20	.08	.04
Sagebrush	.48	.45	.46	.36	.42	.70	.63	.81	.37	.51
TOTAL	1.02	.94	.93	.61	.73	1.33	.99	1.32	.61	.83

2. Continue operating the lysimeters at both the Lower Sheep Creek and Reynolds Mountain experimental sites for defining ET rates.

3. Continue the soil water measuring and data processing program. Soil water accretion and depletion models will be tested with the soil water measurement network.

REPORTS AND PUBLICATIONS

Hanson, Clayton L.
Model for predicting evapotranspiration from native rangelands in the Northern Great Plains. (Accepted for publication in the Trans. ASAE).

WATER QUALITY

Title: Water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed

Personnel Involved:

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
J. F. Zuzel, Hydrologist	Responsible for statistical analysis of data and shares the responsibility for aquatic sampling.
L. V. Street, Biological Technician	Responsible for collection of water samples and laboratory analyses.

Date of Initiation: October 1972

Expected Termination Date: Continuing

INTRODUCTION

In recent years, because of the increased concern for the quality of our environment, many agricultural practices have come under close scrutiny as potential sources of air and water pollution.

In light of P.L. 92-500, "Guidelines for identifying and evaluating the nature and extent of nonpoint source pollution" are needed. When determining pollution from agricultural land it becomes necessary to separate superimposed effects of different land use practices from natural variations in water quality.

Research is needed on the water quality characteristics of rangeland watersheds under natural conditions and under conditions imposed by changes in land use practices. Results from this research should be able to provide a link between downstream water quality and upstream activities and management practices. This information can then be used to determine if the management practices are consistent with downstream water quality objectives or state and/or federal water quality standards.

The Reynolds Creek Experimental Watershed offers an excellent opportunity to study water quality characteristics related to several of the above-mentioned problems. No commercial fertilizers have been used on the watershed. Herbicides were used infrequently for sagebrush control, but not since 1965. The only pesticide used on the watershed was a single application of malathion in July 1975 for grasshopper control.

With the present distribution of hydrologic networks throughout the watershed, sampling of both surface and subsurface flow for water quality analyses can easily be accomplished. The water quality constituents can be related to the hydrology of the system, particularly the properties of the water, the distribution, and the circulation.

The BLM has expressed need for more information on water quality changes influenced by various land management practices. As more rangeland is being used for recreation, this information becomes more important.

Objectives:

To determine water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed as related to:

1. Concentrations of cattle on local areas of rangeland and quasi-feedlot conditions,

2. Irrigation return flow, and

3. Natural soil, geologic, and vegetative conditions.

PROGRESS

The work plan for this year consisted of: (1) determining changes in bacterial quality of free-flowing streams resulting from new grazing management practices; (2) determining variations in water quality of a stream during stormflow; (3) characterizing daily cyclic changes in bacterial concentrations of a stream, and (4) continuing stream monitoring to characterize water quality changes resulting from irrigation return flow.

A total of 21 sites on Reynolds Creek and its tributaries were sampled for bacteria determinations and 7 sites for chemical determinations. Two additional sites were sampled along lower Reynolds Creek for both chemical and bacterial determinations, before Reynolds Creek flows into the Snake River. Figure 1 gives the location of all the sampling sites. Table 1 gives the major water quality characteristics resulting from this year's analyses for the network sampling sites within the watershed. Discussion of the progress on each of the above studies follows.

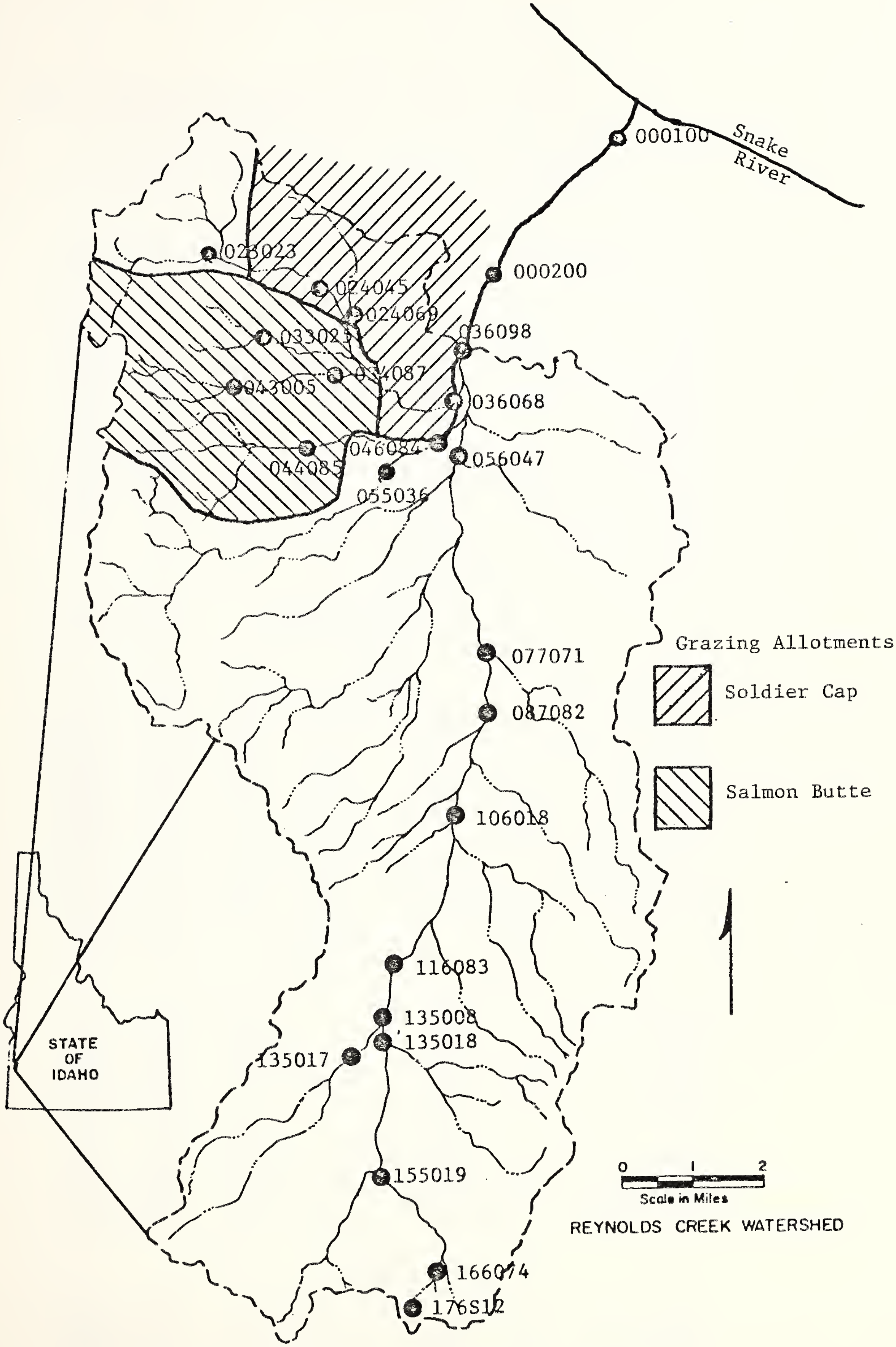


Figure 1. Index Map of Water Quality Sampling Sites, Reynolds Creek Watershed.

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites.

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		REYNOLDS MOUNTAIN SPRING (176S12)			
pH	units	15	7.72	6.24	6.78
Conductivity	μmhos	15	45.00	25.00	34.00
Dissolved solids	mg/l	15	29.25	16.25	22.06
Calcium	mg/l	14	4.41	2.40	3.65
Magnesium	mg/l	14	0.61	0.12	0.41
Sodium	mg/l	14	2.30	1.38	1.71
Phosphorus	mg/l	15	0.03	0.01	0.02
Nitrate	mg/l	15	2.06	0.44	1.44
SiO_2	mg/l	15	12.10	4.00	10.45
Sodium Adsorption Ratio	ratio	14	0.30	0.17	0.23
Suspended solids	mg/l	12	30.00	0.00	7.00
Total coliform	cts/100 ml	20	16	0	3
Fecal coliform	cts/100 ml	20	4	0	0
Fecal strep	cts/100 ml	9	2	0	0
		REYNOLDS MOUNTAIN WEIR (166074)			
pH	units	19	7.93	6.62	7.20
Conductivity	μmhos	19	84.00	25.00	44.00
Dissolved solids	mg/l	19	54.60	16.25	28.46
Calcium	mg/l	19	10.22	2.61	4.40
Magnesium	mg/l	19	7.42	0.24	1.32
Sodium	mg/l	19	5.06	1.84	3.28
Phosphorus	mg/l	19	0.12	0.03	0.05
Nitrate	mg/l	19	0.00	0.00	0.00
SiO_2	mg/l	19	25.60	6.10	19.89
Sodium Adsorption Ratio	ratio	19	0.46	0.27	0.36
Suspended solids	mg/l	15	494.00	0.00	71.00
Total coliform	cts/100 ml	31	10540	0	1141
Fecal coliform	cts/100 ml	31	3000	0	354
Fecal strep	cts/100 ml	22	1040	0	150
		DEMOCRAT (155019)			
pH	units	22	8.19	6.72	7.58
Conductivity	μmhos	22	108.00	31.00	79.00
Dissolved solids	mg/l	22	70.20	20.15	51.20
Calcium	mg/l	22	12.83	4.41	9.13
Magnesium	mg/l	22	2.67	0.61	1.84
Sodium	mg/l	22	5.29	2.76	4.26
Phosphorus	mg/l	22	1.41	0.02	0.16
Nitrate	mg/l	22	0.01	0.00	0.00
SiO_2	mg/l	22	22.90	7.50	17.83
Sodium Adsorption Ratio	ratio	22	0.41	0.31	0.34
Suspended solids	mg/l	18	906.00	0.00	76.72
Total coliform	cts/100 ml	32	1460	0	149
Fecal coliform	cts/100 ml	32	270	0	21
Fecal strep	cts/100 ml	20	280	0	50
		ABOVE DOBSON (135018)			
Total coliform	cts/100 ml	34	3820	0	332
Fecal coliform	cts/100 ml	34	800	0	85
Fecal strep	cts/100 ml	21	520	0	68

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites (Continued)

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		DOBSON (135017)			
pH	units	23	8.18	7.10	7.81
Conductivity	μmhos	23	211.00	70.00	128.00
Dissolved solids	mg/l	23	137.15	45.50	83.48
Calcium	mg/l	23	20.44	7.62	14.13
Magnesium	mg/l	23	2.05	1.46	4.45
Sodium	mg/l	23	7.59	3.45	5.63
Phosphorus	mg/l	22	0.58	0.03	0.12
Nitrate	mg/l	23	0.01	0.00	0.00
SiO_2	mg/l	22	33.30	10.90	26.15
Sodium Adsorption Ratio	ratio	23	0.40	0.27	0.34
Suspended solids	mg/l	18	1214.00	0.00	98.00
Total coliform	cts/100 ml	34	2500	0	447
Fecal coliform	cts/100 ml	34	1215	0	176
Fecal strep	cts/100 ml	21	475	0	80
		BELOW DOBSON (135008)			
Total coliform	cts/100 ml	34	3860	0	424
Fecal coliform	cts/100 ml	34	475	0	80
Fecal strep	cts/100 ml	21	730	0	107
		TOLLGATE (116083)			
pH	units	24	8.34	7.28	7.82
Conductivity	μmhos	24	199.00	55.00	136.00
Dissolved solids	mg/l	24	129.35	35.75	88.29
Calcium	mg/l	24	20.44	6.41	14.27
Magnesium	mg/l	24	8.27	1.70	5.04
Sodium	mg/l	24	8.28	2.99	6.04
Phosphorus	mg/l	23	3.75	0.04	0.39
Nitrate	mg/l	24	0.47	0.01	0.12
SiO_2	mg/l	24	31.60	10.30	25.54
Sodium Adsorption Ratio	ratio	24	0.40	0.27	0.35
Suspended solids	mg/l	19	10000.00	0.00	773.00
Total coliform	cts/100 ml	37	1840	0	248
Fecal coliform	cts/100 ml	37	400	0	47
Fecal strep	cts/100 ml	24	540	0	52
		GABICA (106018)			
Total coliform	cts/100 ml	33	1120	0	146
Fecal coliform	cts/100 ml	33	560	0	53
Fecal strep	cts/100 ml	21	740	0	87
		NETTLETON (087082)			
Total coliform	cts/100 ml	39	6750	10	739
Fecal coliform	cts/100 ml	39	1664	0	202
Fecal strep	cts/100 ml	26	2180	0	340
		TYSON (077071)			
Total coliform	cts/100 ml	33	1940	20	466
Fecal coliform	cts/100 ml	33	552	0	127
Fecal strep	cts/100 ml	21	2750	8	349

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites (Continued)

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		LOWER REYNOLDS (056047)			
pH	units	28	8.32	7.37	7.94
Conductivity	μmhos	28	1110.00	116.00	476.00
Dissolved solids	mg/l	28	721.50	75.40	309.51
Calcium	mg/l	27	84.37	10.42	39.03
Magnesium	mg/l	27	26.02	3.16	12.01
Sodium	mg/l	27	138.39	8.05	52.49
Phosphorus	mg/l	27	3.13	0.06	0.57
Nitrate	mg/l	28	0.55	0.02	0.16
SiO_2	mg/l	28	41.80	12.80	30.46
Sodium Adsorption Ratio	ratio	27	3.62	0.56	1.68
Suspended solids	mg/l	19	11044.00	2.00	701.00
Total coliform	cts/100 ml	38	3000	20	532
Fecal coliform	cts/100 ml	38	4000	0	350
Fecal strep	cts/100 ml	24	4620	5	614
		UPPER MACKS (055036)			
Total coliform	cts/100 ml	13	1750	5	232
Fecal coliform	cts/100 ml	13	540	0	68
Fecal strep	cts/100 ml	13	10540	0	1296
		MACKS CREEK (046084)			
Total coliform	cts/100 ml	15	7200	10	679
Fecal coliform	cts/100 ml	15	2264	0	236
Fecal strep	cts/100 ml	3	42	16	28
		COTTLE CREEK (044085)			
Total coliform	cts/100 ml	16	2170	0	390
Fecal coliform	cts/100 ml	16	950	0	117
Fecal strep	cts/100 ml	16	1490	2	170
		UPPER MURPHY (043005)			
Total coliform	cts/100 ml	6	2650	40	935
Fecal coliform	cts/100 ml	6	420	0	167
Fecal strep	cts/100 ml	6	300	10	125
		SALMON (036098)			
Total coliform	cts/100 ml	33	8050	0	722
Fecal coliform	cts/100 ml	33	4160	0	216
Fecal strep	cts/100 ml	21	2220	0	292
		OUTLET WEIR (036068)			
pH	units	25	8.74	7.46	8.02
Conductivity	μmhos	25	1157.00	128.00	520.00
Dissolved solids	mg/l	25	725.05	83.20	337.63
Calcium	mg/l	25	79.56	11.62	38.99
Magnesium	mg/l	25	34.04	3.04	14.28
Sodium	mg/l	25	142.53	8.74	56.90

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites (Continued)

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		OUTLET WEIR (036068)			
Phosphorus	mg/l	24	4.62	0.02	0.58
Nitrate	mg/l	25	0.97	0.05	0.28
SiO_2	mg/l	25	37.40	13.60	30.94
Sodium Adsorption Ratio	ratio	25	3.80	0.55	1.78
Suspended solids	mg/l	18	8690.00	0.00	696.00
Total coliform	cts/100 ml	37	6500	20	610
Fecal coliform	cts/100 ml	37	864	0	140
Fecal strep	cts/100 ml	24	1160	4	355
		LOWER MURPHY (034087)			
Total coliform	cts/100 ml	2	260	240	250
Fecal coliform	cts/100 ml	2	170	0	85
Fecal strep	cts/100 ml	2	180	120	150
		FARROT CREEK (033005)			
Total coliform	cts/100 ml	3	2900	200	1463
Fecal coliform	cts/100 ml	3	1164	300	808
Fecal strep	cts/100 ml	3	961	89	320
		BOSTON DITCH (024069)			
Total coliform	cts/100 ml	4	860	360	585
Fecal coliform	cts/100 ml	4	370	240	305
Fecal strep	cts/100 ml	4	180	10	120
		UPPER SALMON (024045)			
Total coliform	cts/100 ml	14	2900	5	349
Fecal coliform	cts/100 ml	14	2790	0	230
Fecal strep	cts/100 ml	13	1260	0	175

Bacterial quality changes resulting from grazing management practices:

The Bureau of Land Management put into effect a new grazing allotment plan on Reynolds Creek during the 1975 grazing season. To determine the effect this management plan had on the bacterial quality of streamflow, sites 024045, 024069, 033025, 034087, 043005, and 044085 were monitored during the grazing season in the northeast part of the watershed. Two fenced allotments were used for this study. Figure 1 shows location of sampling sites and the grazing allotments. Two sampling sites were located in the Soldier Cap allotment and four in the Salmon Butte allotment. The allotment plan called for approximately 615 cattle to be moved into the Soldier Cap allotment on May 1 and remain there through May 15. The cattle would then be moved out of the Soldier Cap allotment into the Salmon Butte allotment, and remain there through June 15. The cattle would be moved out of the Salmon Butte allotment at this time into adjacent allotments. Results of sampling prior to, during, and after the grazing season are given in Figures 2 and 3. Fecal coliform bacteria is used to illustrate the changes because it is the best indicator of bacterial pollution from warm-blooded animals. Total coliform and fecal strep concentrations were determined, also. Samples were taken weekly from April 22 through September 22. As seen in Figure 2, Soldier Cap allotment, no fecal counts were recorded from April 22 until approximately May 15. The concentrations remained high through June 24. By July 7 the concentrations were nearly zero.

Figure 3 shows the same characteristics for the Salmon Butte allotment. No fecal counts were recorded until June 3 and started decreasing rapidly after June 24.

These data indicate that the introduction of cattle into these allotments had a very sudden effect on the bacterial quality of the water.

On July 21, a high intensity summer storm passed through this area, causing high runoff. As seen in both Figures 2 and 3, the "flushing" effect of the runoff resulted in concentrating the residual bacteria into the stream even though the cattle had been out of the area by as much as 3 weeks. More frequent sampling is planned next year to better define runoff-induced concentrations.

Water quality changes occurring during stormflow:

An insufficient number of samples were collected for chemical analyses to characterize chemical quality variations during stormflow. Samples were collected for bacterial analyses during several runoff events from snowmelt. Because of insufficient incubator space, it was not possible to sample completely through any one peak flow. A composite of results for several peak flows for site 036068 is given in Figure 4. The few samples that were analyzed show that considerable changes occur in bacterial concentrations during high runoff. Figures 4A and 4B show

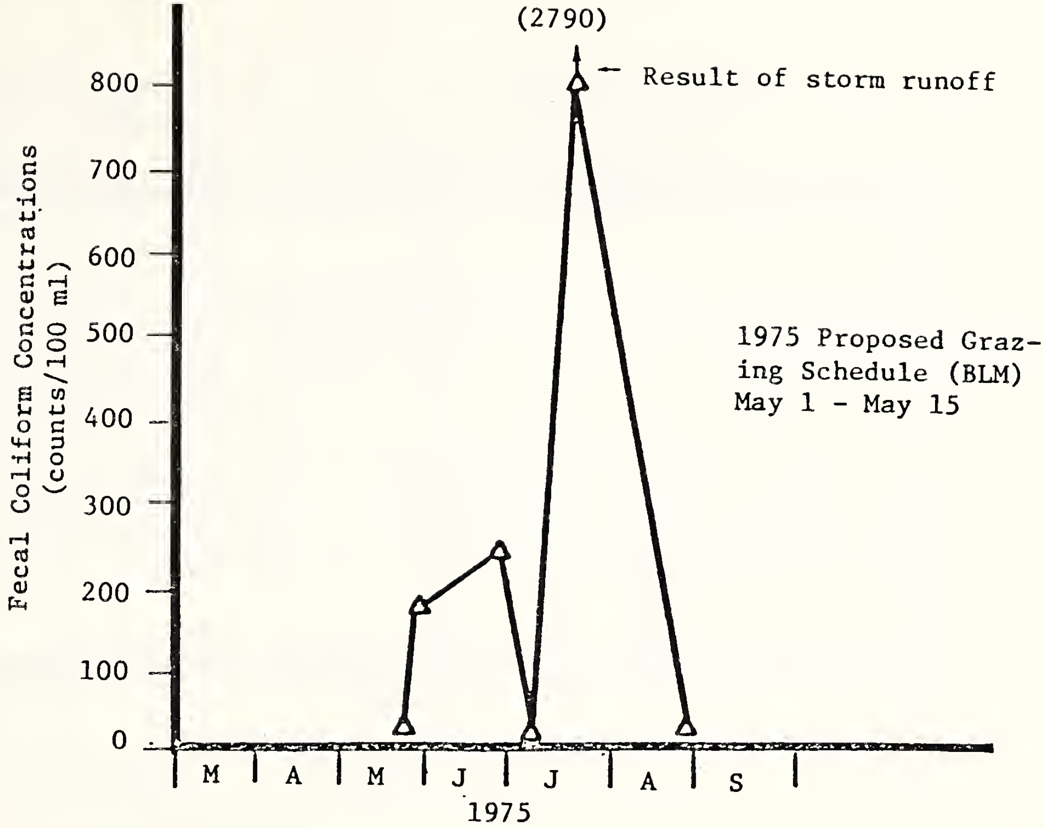


Figure 2. Average fecal coliform concentrations from sample sites in Soldier Cap Grazing Allotment.

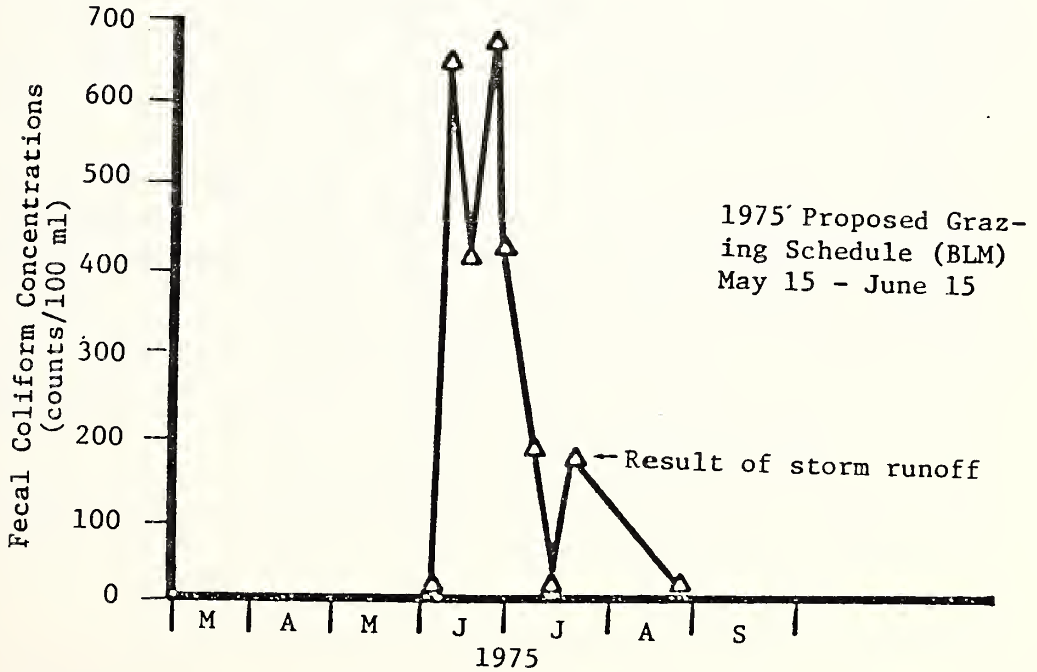


Figure 3. Average fecal coliform concentrations from sample sites in Soldier Cap Grazing Allotment.

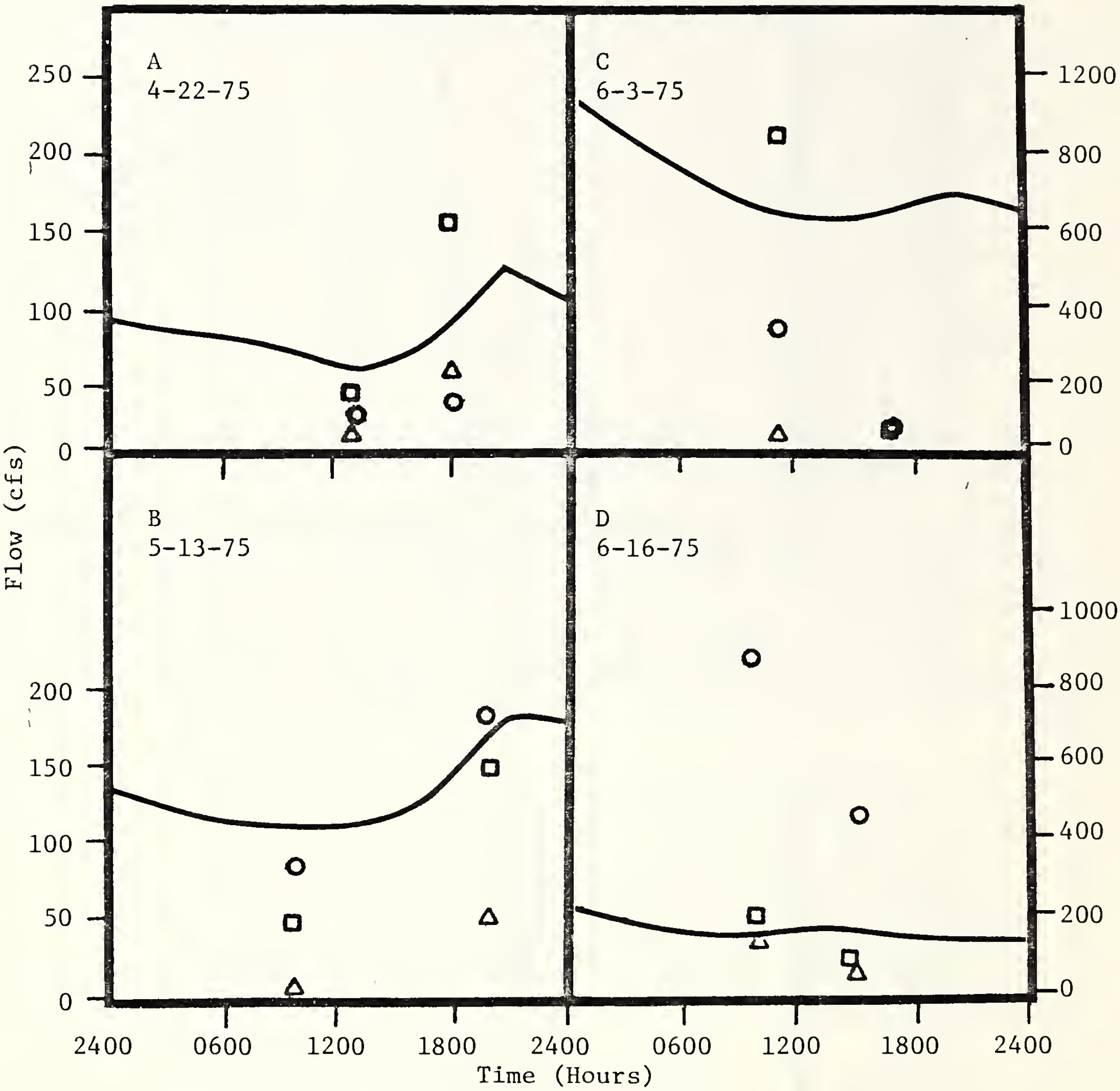


Figure 4. Bacterial variations related to streamflow at site 036068. Total coliform counts indicated by (□); fecal coliform counts by (Δ); and fecal strep by (O).

that total coliforms and fecal strep increase most rapidly on the rising limb of the hydrograph with less of an increase in fecal coliforms. Results from the samples collected during receding flow, Figures 4C and 4D, show that bacterial concentrations are reduced quite rapidly during the recession of flow.

Data from these incomplete investigations during runoff peaks from snowmelt indicate that a "flushing" effect occurs along the banks of streams as the water rises. No overland flow or sheet flow occurred near these sampling sites during these events.

No intense sampling throughout the rising and receding stages of a rainfall-runoff event was done. However, several samples were collected on regular schedules during the year at various intervals during rainfall runoff. The higher runoff from these events shows a similar "flushing" effect, resulting in somewhat higher bacterial concentrations at most sites.

Characterizing daily cyclic changes in bacteria concentrations:

During regular sampling and analysis procedures, it became obvious that a cyclic variation in bacterial concentrations occurs. This cyclic variation is probably the result of several factors of the stream environment, such as temperature, stage and solar radiation. To characterize these differences for several sites, a study was made after the major runoff season when the stream stage was rather constant, eliminating that factor. Two sites were sampled hourly over 24-hour periods, recording air and water temperature, pH, dissolved oxygen, and alkalinity. A qualitative record was made of cloud cover. A third study was made in October, when the stream stage was still constant, but a solarimeter was used to monitor quantitatively the incoming solar radiation. Both shaded and unshaded samples were used for the latter study.

Figure 5 gives the results of total, fecal, and fecal strep concentrations for the first 24-hour study at site 043005 on June 30 - July 1, 1975. Stream temperature and qualitative description of cloud cover is also given. No appreciable changes occurred in pH, dissolved oxygen, or alkalinity. Variations occur in all three bacterial types for this study, with highest counts recorded during periods of cloud cover or darkness. Temperature appears to have some affect in the early daylight hours, but seems to be overcome very rapidly by the effect of solar radiation.

The second 24-hour study was undertaken at site 023023, on July 17-18. Figure 6 gives the results of this study. As in the first study, pH, dissolved oxygen, and alkalinity show no appreciable variation.

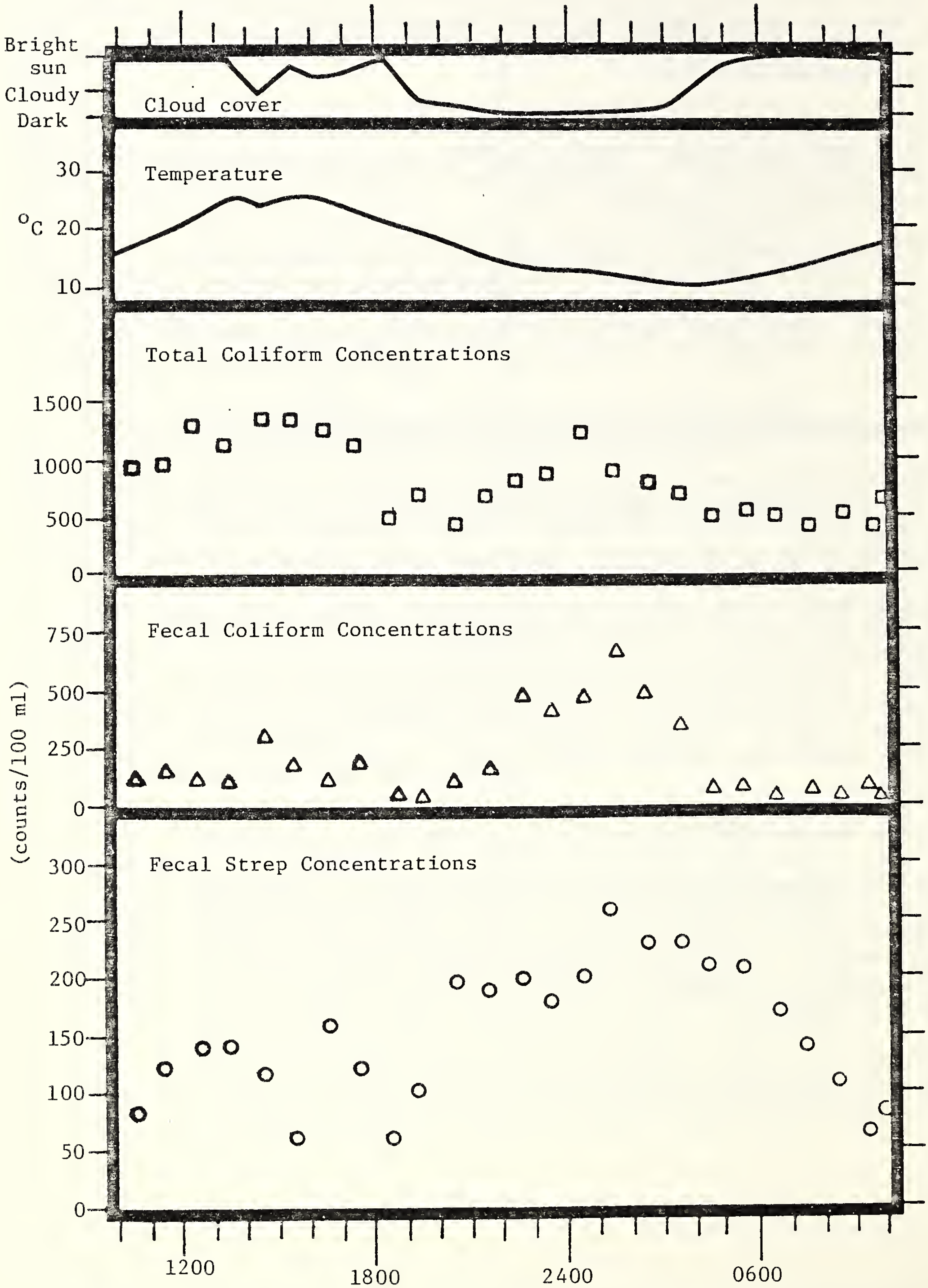


Figure 5. Twenty-four hour study at site 043005, June 30-July 1.

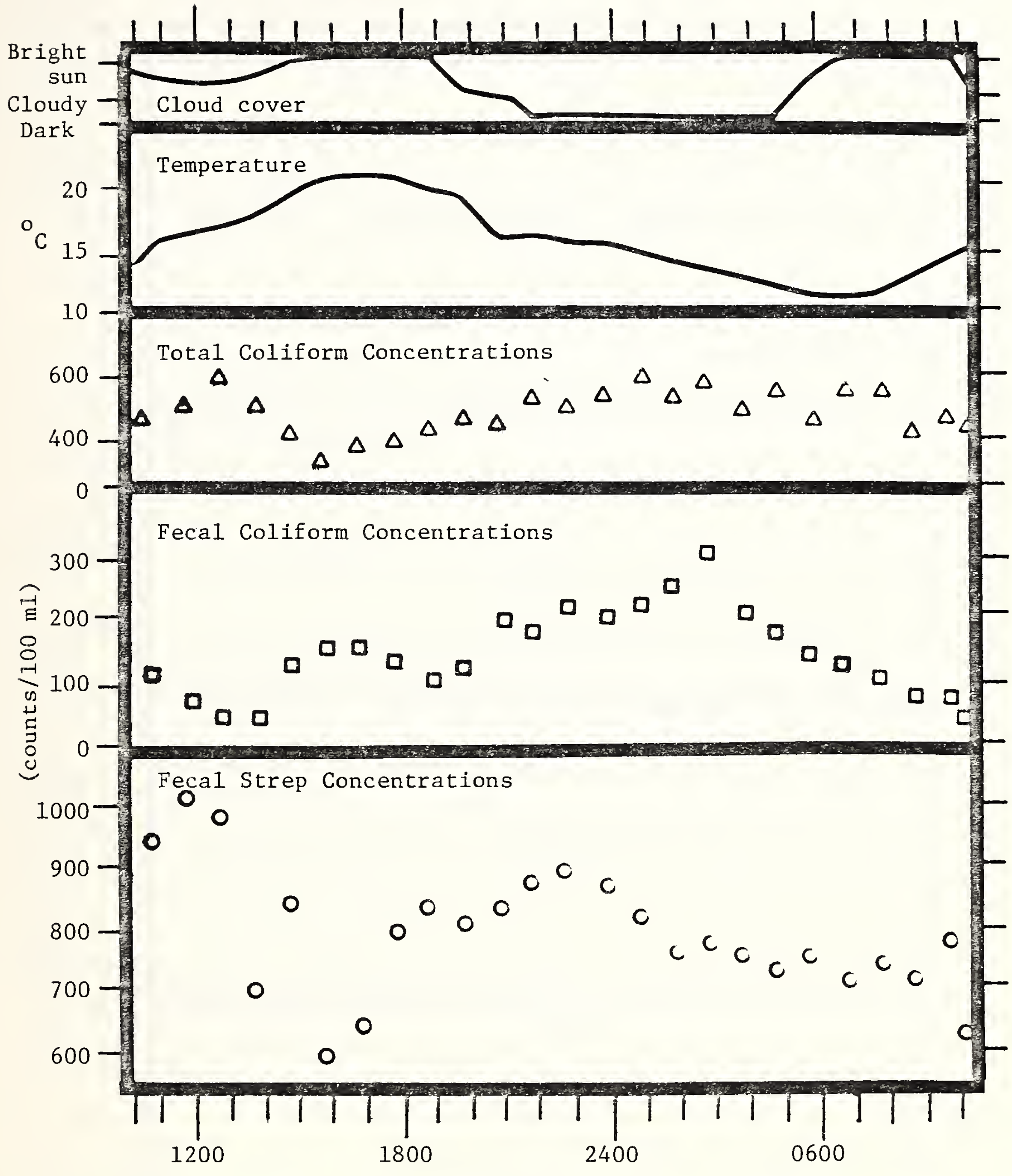


Figure 6. Twenty-four hour study at site 023023, July 17-18.

The same characteristic features of bacterial variations occur in this study that were found to occur during the first 24-hour study. Namely, that bacterial growth appears to increase in morning hours and then drop off rapidly during maximum daylight hours, then increase again during darkness.

To determine more quantitatively the effect of solar radiation on bacterial growth in natural waters, a third study was conducted on October 15, at site 135008. The streamflow was constant and water temperature was cool and did not vary much during the study. A solarimeter with continuous recorder was used to record incoming solar radiation. Dissolved oxygen and pH were also determined during sampling, but again the variations were only slight. Eight, 400 milliliter samples were collected in the early morning and kept in a frame directly in the stream so that the temperatures would remain approximately the same with the flowing water. Four of the sample containers were covered (shaded) so that air could pass over them, and four samples were left unshaded. Samples for bacterial analyses were collected from each set of containers and from the stream each hour for analysis, and temperatures recorded. Results of this study, which was conducted during daylight hours only, are given in Figure 7. The differences in water temperature of the 400 ml containers and the flowing water in the stream never exceeded 1° C.

Bacterial growth for the shaded samples show slight increased growth or remain relatively stable during hours of maximum solar radiation. For the unshaded samples, all bacteria types show a decrease in concentrations during hours of maximum solar radiation.

Upon closer examination of the data, we find that 70 percent of all the unshaded samples resulted in lower bacterial concentrations. The total and fecal coliforms average 40 percent reduction in counts, and the fecal strep averaged 28 percent reduction. Over 90 percent of the reduction occurred in those samples collected after 1100 hours.

The sterilization effect of ultraviolet radiation is well known. Ultraviolet waves occur naturally in solar radiation and, as can be seen from the results of these studies, are probably responsible for the reduced concentrations of bacterial organisms in natural waters during periods of sunlight. This is most evident during the summer months and should be considered when determining the bacterial quality of free-flowing streams.

Water quality changes during irrigation season:

The following discussion is set up for comparison with the last 2 years' results. A comparison of selected chemical parameters is given in Figures 8 and 9 for two sites; Tollgate, characterizing streamflow from

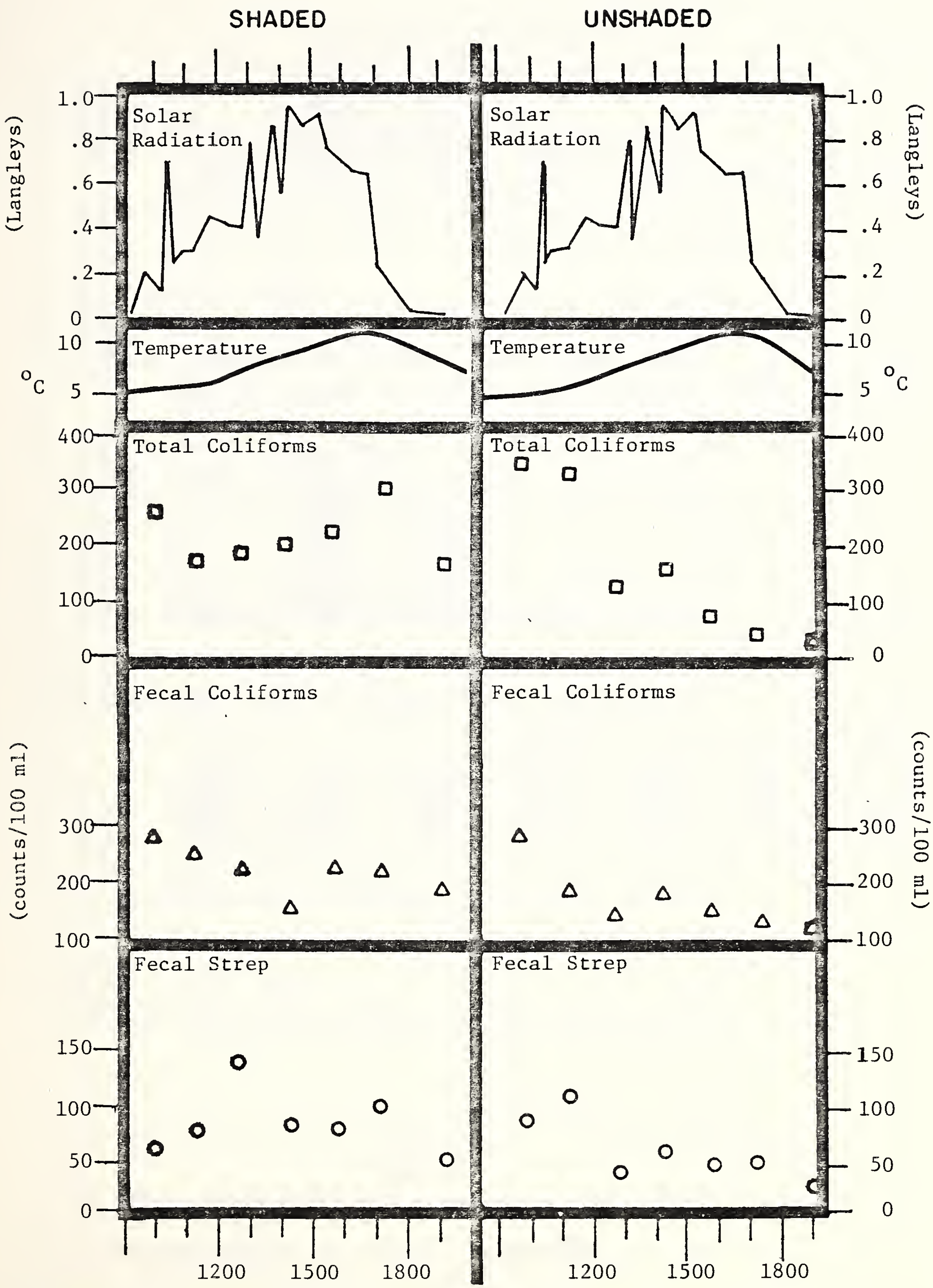


Figure 7. Twenty-four hour study at site 135008, October 15.

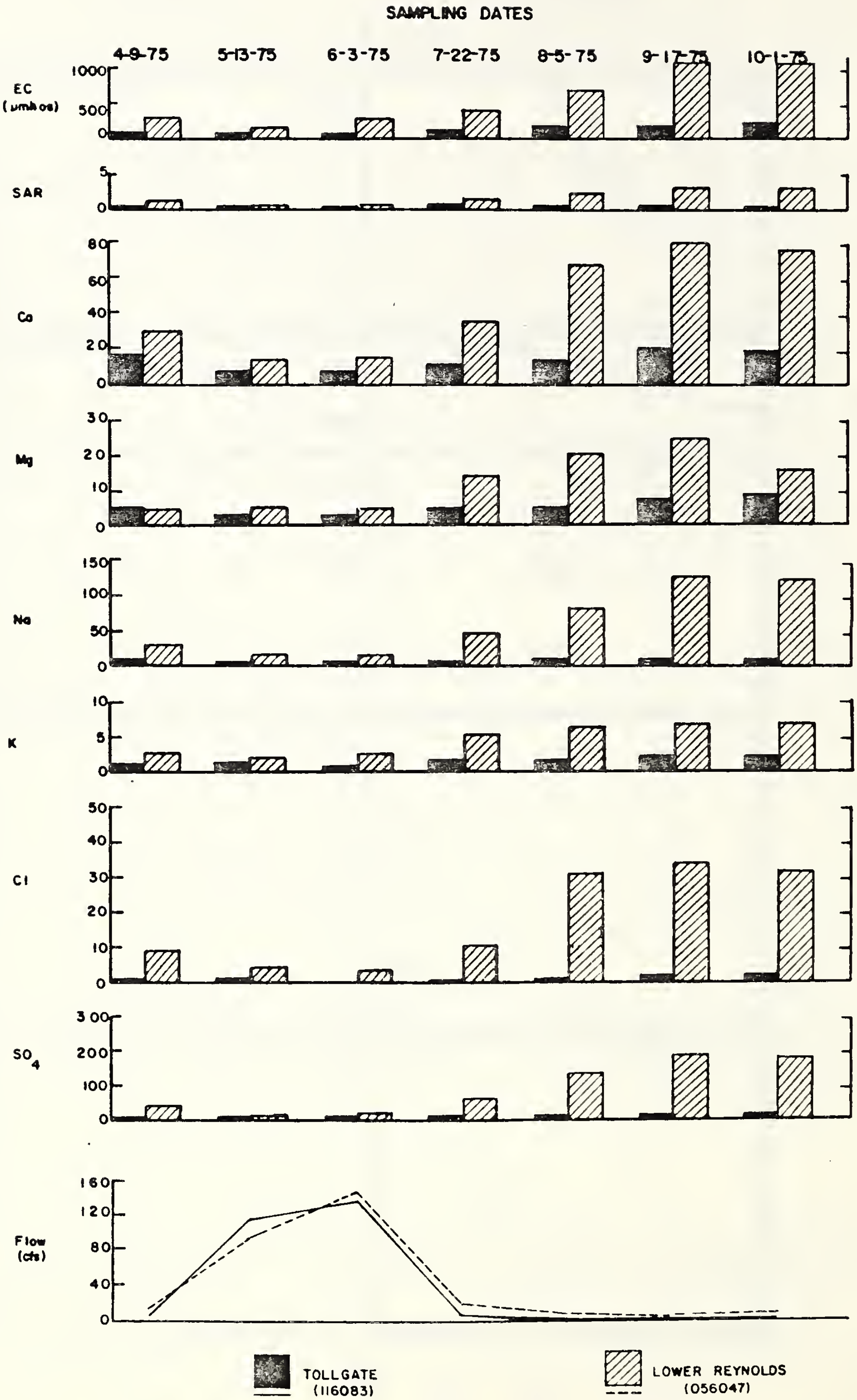


Figure 8. Major chemical constituents (mgl) and channel flow at sites on Reynolds Creek.

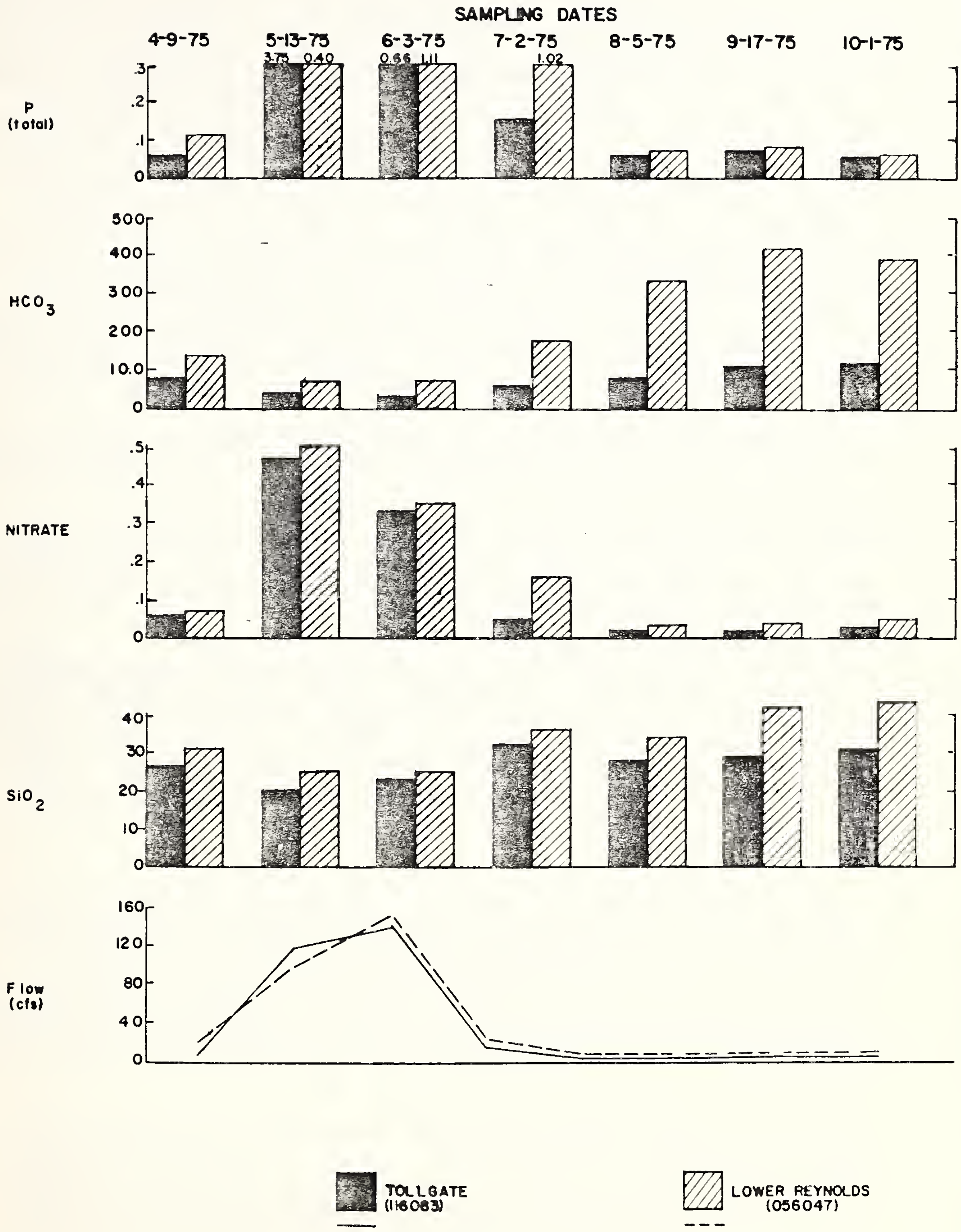


Figure 9. Major chemical constituents (mgl) and channel flow at two sites on Reynolds Creek.

open range, and Lower Reynolds, characterizing irrigation return flow. As in the previous 2 years, marked changes occur in levels of concentration at the Lower Reynolds site during the irrigation season, while levels of concentration at the Tollgate site remain relatively constant.

The streamflow regime for 1975 was considerably different during April, May, and June, than in 1974. It was characterized by higher flows from snowmelt runoff and by several runoff events from rainstorms. This difference in flow regime also changed the water chemistry slightly during the early spring, particularly in the soluble ions of phosphorus and nitrate, increasing the level of concentration of these ions considerably at both sites. The higher level of concentration for most ions during early April is the result of lower flow at the time. As in the previous 2 years, nearly all the cations increase rapidly during the irrigation season as irrigation return flow increases their levels of concentration as the volume of water in the channel decreases.

The phosphate ions, occurring from natural sources, show highest levels of concentration during peak flows, illustrating their affinity to adsorb, mainly to suspended sediment particles.

Again, there appears to be no sodium alkali hazard in Reynolds Creek waters, as indicated by the low sodium adsorption ratio. However, the conductivity values indicate that there continues to be a rapid salinity increase during the irrigation season.

The overall chemical quality of Reynolds Creek water remains good except in the lower reaches of the valley when irrigation runoff and low flow results in a rapid increase in salinity. No appreciable deterioration in chemical quality of Reynolds Creek occurs during the rest of the year. There remains no evidence that any chemical quality deterioration occurs as a result of livestock operations on open range.

Water quality standards:

Some additional work was done this year on examining nonpoint source runoff in light of present water quality standards. Sufficient bacterial data has been collected and analyzed so that some preliminary results can be given. Total coliforms, fecal coliforms, and fecal streptococcus were sampled for this purpose. The fecal coliform group will be used herein because these bacteria are associated directly with the feces of warm-blooded animals, and their presence would imply contamination.

Data from two sites along Reynolds Creek are used to illustrate the affect agricultural runoff in this area has on the bacterial quality of the water. Figure 10 gives a probability plot of fecal coliform counts from 76 samples at site 036068. This site is located at the

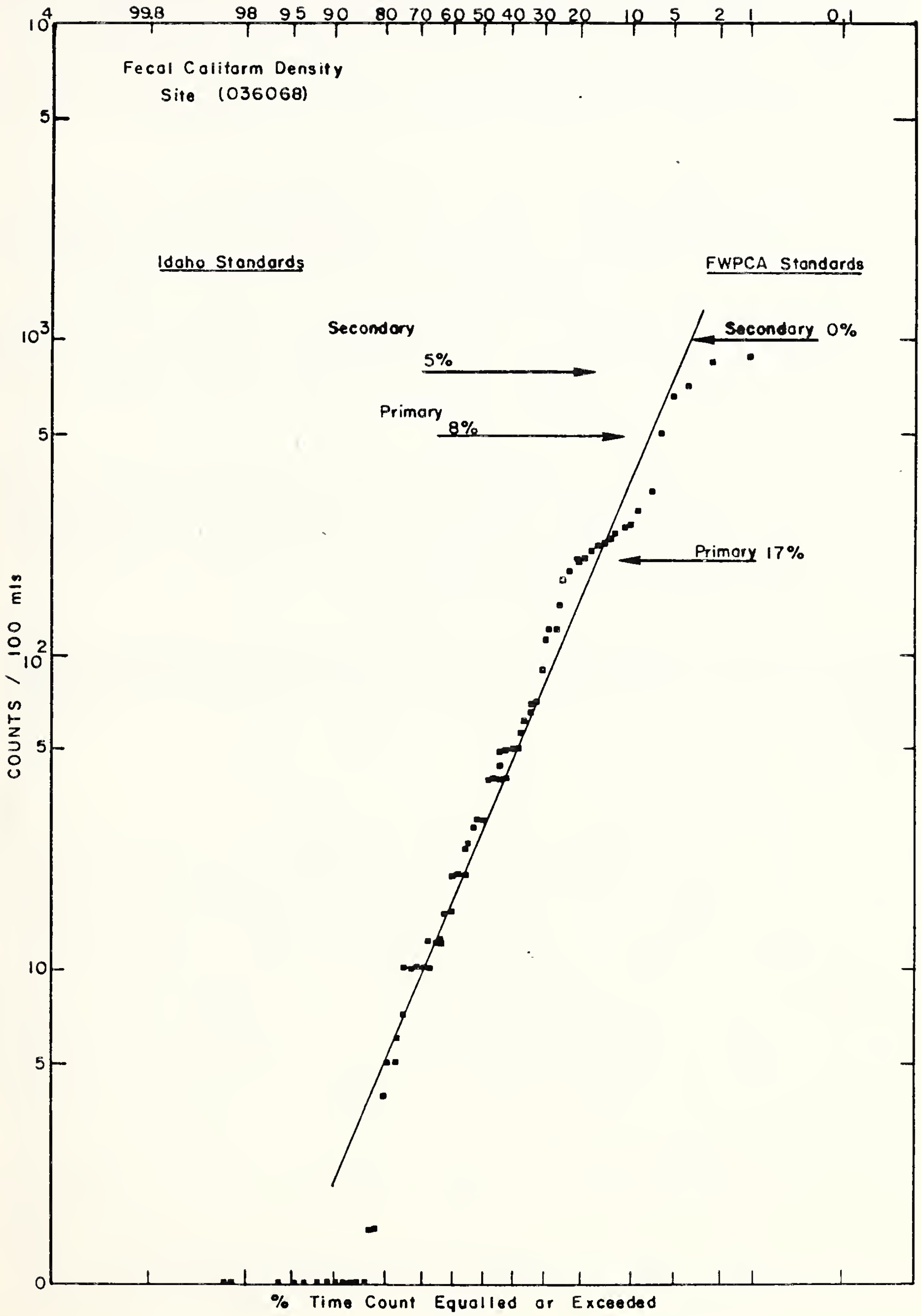


Figure 10. Fecal coliform counts at site 036068.

outlet of the Reynolds Creek Watershed and includes the runoff from the entire 90-square miles. The data are compared with the water quality recommendations given both by the State of Idaho (1), and the federal government (2), for both primary and secondary contact recreational waters. From Figure 10 it can be seen that the Idaho standards for primary contact are exceeded 8 percent of the time and 5 percent for secondary contact. The federal standards were exceeded 17 percent of the time at this site for primary contact, but not exceeded for secondary contact.

The second site used for this study, 000100, was located on Reynolds Creek about 50 yards upstream from its confluence with the Snake River. Figure 11 gives the probability plot of fecal coliform counts for 51 analyses at this site. The Idaho standards for primary contact recreational waters were exceeded 30 percent of the time and 21 percent of the time for secondary contact. The federal standards were exceeded 52 percent of the time for primary contact recreational waters and 18 percent of the time for secondary contact.

This site is located immediately below irrigated pastures where cattle graze year around. Runoff from these fields and from agricultural land, both irrigated and open range, flow through this site. The Reynolds Creek water, after passing through this site, immediately joins the Snake River, a high-use recreational stream.

The data presented herein are only preliminary results for this study. Additional work is being done at sites along Reynolds Creek and its tributaries to determine more precisely nonpoint source contamination on rangeland.

Aquatic insect investigations:

A serious grasshopper invasion this year resulted in the application of malathion (95 percent technical grade, at the rate of 8 fluid ounces per acre) over 22,500 acres of rangeland on the Reynolds Creek Watershed. The total effort was coordinated by the Animal, Plant Health Inspection Service, USDA, and included state, private, and federal grazing land. Samples of aquatic insects were collected before, during, and after spraying to determine the effect of the pesticides on these nontarget organisms. The area was sprayed by fixed-wing aircraft during the early hours of July 19-21. Five samples were taken on 12 days -- July 17, 18, 21, 22, 25, 28, 29, and August 1, 4, 11, 18, and 25. The data given in Figure 12, ratio of dead to live organisms at the sampling site, indicate the dramatic mortality of the aquatic ecosystem to the application of malathion. Further, there is evidence to indicate that the kill was not immediate on all organisms but took some time to cause death. It was also determined that the effects of the pesticide are fairly short lived since the data suggest that total numbers of organisms recovered to expected levels within a month after application of the pesticide.

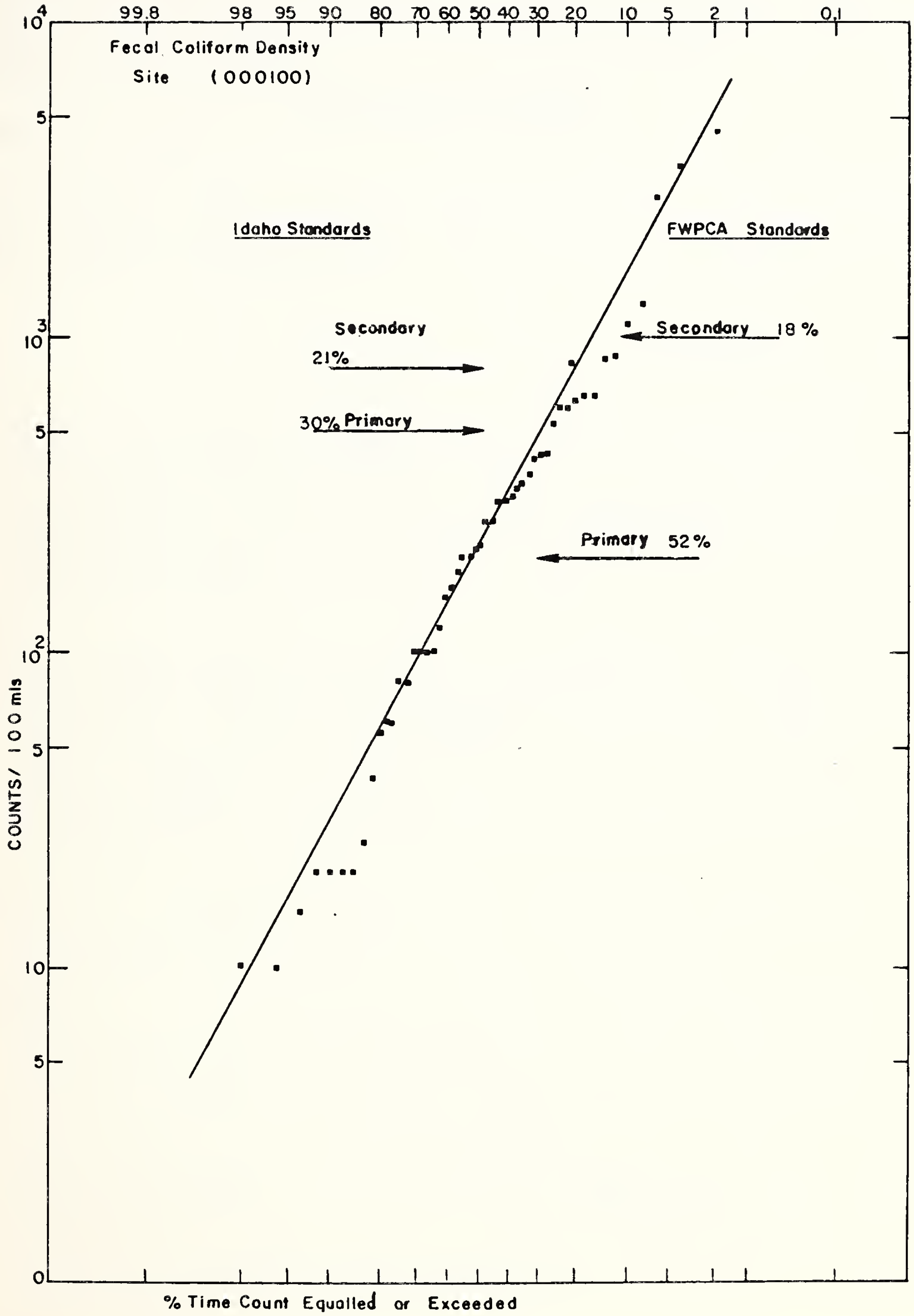


Figure 11. Fecal coliform counts at site 000100.

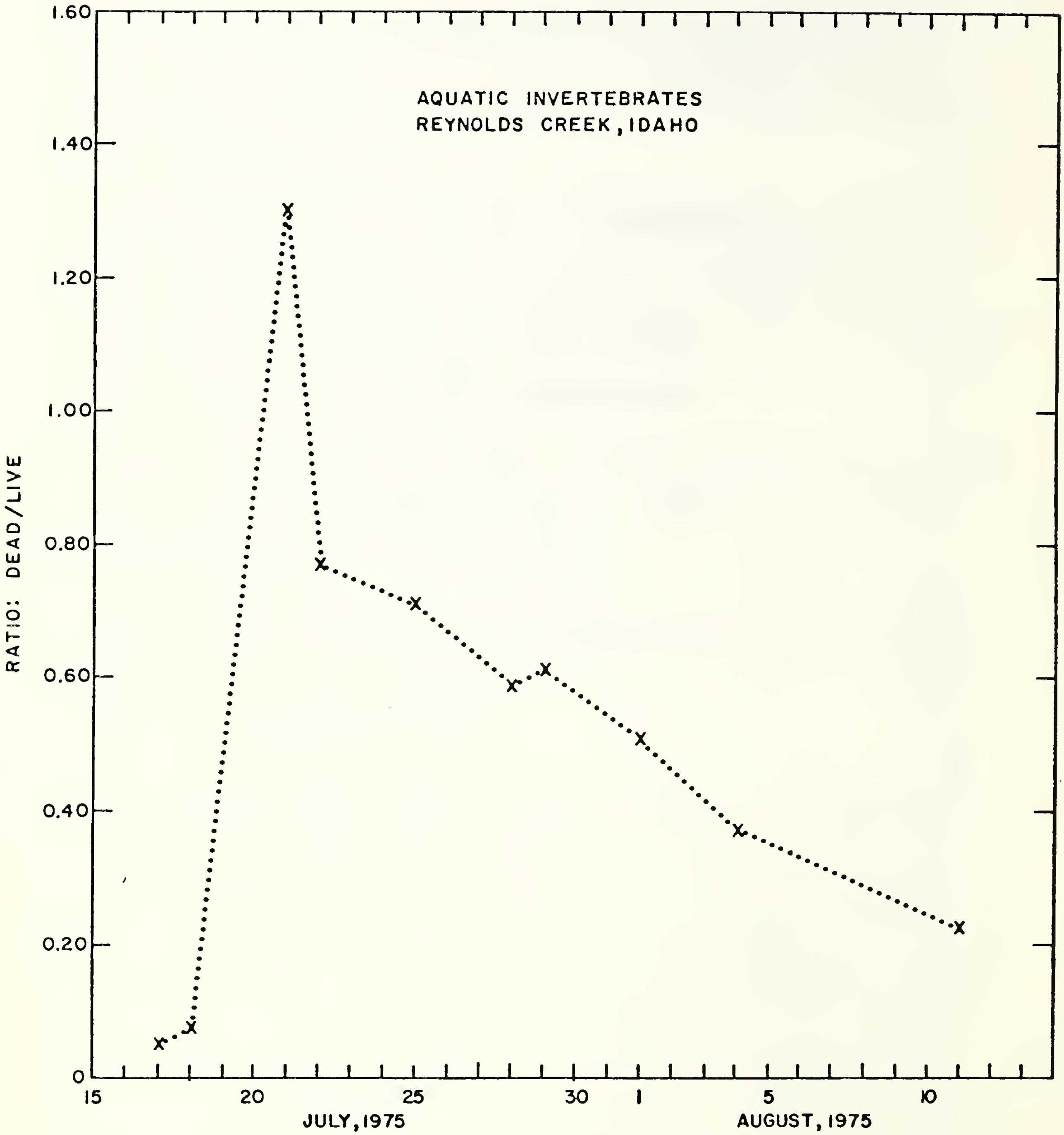


Figure 12. Ratio of live to dead organisms.

Pesticide concentrations in the water were not determined, so toxicity information could not be compared with lethal concentrations reported by other investigators.

Standard ionic concentrations of the stream were determined during the sampling period and were found to remain quite stable.

Water quality model:

Several modifications have been made this year in the Idaho Water Resources water quality model in trying to adapt it to Reynolds Creek data. Several adjustments have yet to be made, so there are no results to be reported for this year.

SIGNIFICANT FINDINGS

1. Bacterial data collected from sites within the newly adopted BLM grazing management plan show that a very sudden rise in fecal coliform concentrations occurs in stream water in these allotments as soon as cattle are turned in. The counts remain high until the cattle are moved out, and then lower rapidly. Residual fecal coliforms remain in the soils and are flushed into the streams by runoff from storms.

2. The "flushing" effect from residual bacteria colonies occurs from both snowmelt runoff and higher intensity rainfall-runoff events. Residual colonies occur throughout the range, as well as the irrigated pastures from along the streams to high on the slopes. The character of the overland flow-runoff on frozen soil, summer thunderstorms, or normal snowmelt runoff -- appears to characterize the variation on bacterial concentrations during stormflow.

3. Results of the study on the influence of solar radiation on bacterial growth determined that solar radiation can reduce bacterial concentrations by as much as 40 percent.

4. Nonpoint source pollution studies indicate that 5 percent to 30 percent of the samples collected at two sites along Reynolds Creek, exceeded Idaho state standards for primary and secondary contact recreational waters. Federal standards were exceeded by as much as 52 percent.

5. Malathion used for aerial spray of grasshoppers on open range resulted in a drastic kill of aquatic insects. However, the kill was not permanent and the number of organisms recovered to prespray levels within 30 days.

WORK PLAN FOR FY 77

1. The present sampling network for monitoring chemical quality of Reynolds Creek will be reduced to two sites -- 036008 and 116083. Increased sampling will occur during high runoff events to determine specific changes related to changes in flow regime. Newly received incubators will permit us to sample for bacterial variations through runoff events to determine the effect changes in streamflow have on bacteria group concentrations.

2. Nonpoint source determination will be made at numerous sites in new grazing allotments and in irrigated pastures for comparison with present water quality standards for recreational waters. The ratio of fecal coliform to fecal strephococcus will be used. Several different types of agar and broth will be tested to determine which type of growth media give best results.

3. Additional sites in new grazing allotments under various use conditions will be monitored to determine the effect of the new grazing program on water quality resulting from agricultural runoff.

REFERENCES CITED IN TEXT

Water Quality Standards and Wastewater Treatment Requirements, Idaho Department of Environmental and Community Services, Boise, Idaho, June 1973.

A Report of the Committee on Water Quality Criteria, Fed. Water Poll. Control Adm., U.S. Dept. of Interior, Washington, D. C. 1968.

REPORTS AND PUBLICATIONS

Zuzel, J. F. and G. R. Stephenson
Malathion induced mortality in an aquatic insect ecosystem. Unpublished report.

Water quality investigations on the Reynolds Creek Watershed. Southwest Idaho - A three-year progress report (In preparation).

RUNOFF AND SEDIMENT

Title: Sediment yield and runoff from rangeland watersheds

Personnel Involved:

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agricultural Engineer	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, Hydrologic Technician	Data collection, compilation, and analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and recording system and radio telemetry systems.

Date of Initiation: September 1, 1969

Expected Termination Date: Continuing

INTRODUCTION

Information on sediment yield is almost entirely lacking for millions of acres of predominantly sagebrush rangeland under government land management and private ownership in the Northwestern United States. There is a growing concern for soil losses from intensively grazed rangelands, sediment damage to reservoirs, and erosion of stream channels.

Most rangeland watersheds in the Intermountain Northwest have large areas of relatively steep hillslope topography, and these areas need to be delineated for treatment to reduce erosion. Also, sediment yield information is needed for evaluating the benefits of watershed management and land treatment programs of the Bureau of Land Management and Soil Conservation Service.

Range sites found in the Reynolds Creek Experimental Watershed represent a large percentage of the rangeland in the Northwest, and studies of sediment yield are essential for developing sound management practices and planning appropriate multiple use of these lands. Good land management decisions require information on how vegetative changes, fencing, and land use alter the sediment yield potential of rangeland watersheds.

The sources of these sediments need to be determined so that research data can be used to predict sediment yield for ungaged areas in terms of available information on soils, climate, physiography, and use. Research is also needed to adapt the Universal Soil Loss Equation, the Flaxman Equation, and similar procedures to rangelands.

Objectives:

1. To determine precipitation-snowmelt-runoff relationships and to test watershed runoff models on rangeland watersheds.

2. To determine the relationships between sediment yield and variables describing hydraulic and hydrologic factors and site and watershed characteristics that influence sediment yield.

3. To test presently used erosion and sediment yield procedures, utilizing Reynolds Creek Watershed Data.

4. To develop and test improved erosion and sediment yield prediction procedures for rangeland watersheds in the northwest.

Suspended and bedload sediment yields from plots, channels, and watersheds are measured by pumping sediment samplers, splitting devices, catchments, and hand sampling. Plots, microwatersheds, and watersheds are equipped for runoff measurement and are located on various soil types in different precipitation zones. A wide range of slope length, slope area, aspect, and relief ratio are represented. Rainfall intensity and duration data are available from a network of precipitation gages, and snow data are available from snow courses, snow pillows, and other snow-measuring sites. Also, data on cover, topography, and soil factors (including frost depths), which influence erosion and sedimentation, are available through other investigations at the Northwest Watershed Research Center.

PROGRESS

Runoff and sediment measurement:

Watersheds and plots instrumented for runoff and sediment measurement in 1975 on the Reynolds Creek Experimental Watershed are listed and described in Table 1. Locations of the measurement sites are shown in Figure 1. Three source watersheds and four plots were discontinued January 1, 1976.

TABLE 1.--Plots and watersheds instrumented for runoff and sediment measurement, Reynolds Creek Watershed, December 1974.

Watershed or Plot NAME	No.1/	Drainage Area (Acres)	Runoff Measuring Device	Suspended Sediment Sampler	Bedload Sediment Sampler
Reynolds Creek Outlet	1	57700	SCOV Weir	P.S. 67 Pump	Helley-Smith
Salmon Creek	2	8990	Drop-Box Weir	Hand Held	Helley-Smith
Murphy Creek	3	306	Drop-Box Weir	Hand Held	Detention Pond
Macks Creek	4	7846	Drop-Box Weir	P.S. 67 Pump	Helley-Smith
Summit2/	5	205	Drop-Box Weir	Gravity Flow	Detention Pond
Flats	6	2.24	V-Notch Weir	Single Stage	Detention Tank
Nancy Gulch	7	3.1	V-Notch Weir	Single Stage	Detention Tank
Whiskey Hill2/	8	119	V-Notch Weir	Hand Held	Detention Pond
Lower Sheep	9	33	Drop-Box Weir	Hand Held	Detention Box
Upper Sheep2/	10	63.4	Drop-Box Weir	Chickasha Pump	Detention Box
Reynolds Tollgate	11	13453	Drop-Box Weir	P.S. 67 Pump	Helley-Smith
Reynolds Mountain	12	100	V-Notch Weir	Chickasha Pump	Detention Box
PLOTS					
Summit2/	5	ALL PLOTS:	14 feet wide, 72.6 feet long V-Notch Weirs, single stage samplers, overflow sample tank, and settling tank.		
Windy Point2/	13				
Nancy Gulch	7				
Upper Sheep2/	10				
Nettleton	14				
Reynolds Mountain2/	12				

1/ Numbers designate locations of weirs and plots in Figure 1.
2/ Discontinued January 1, 1976

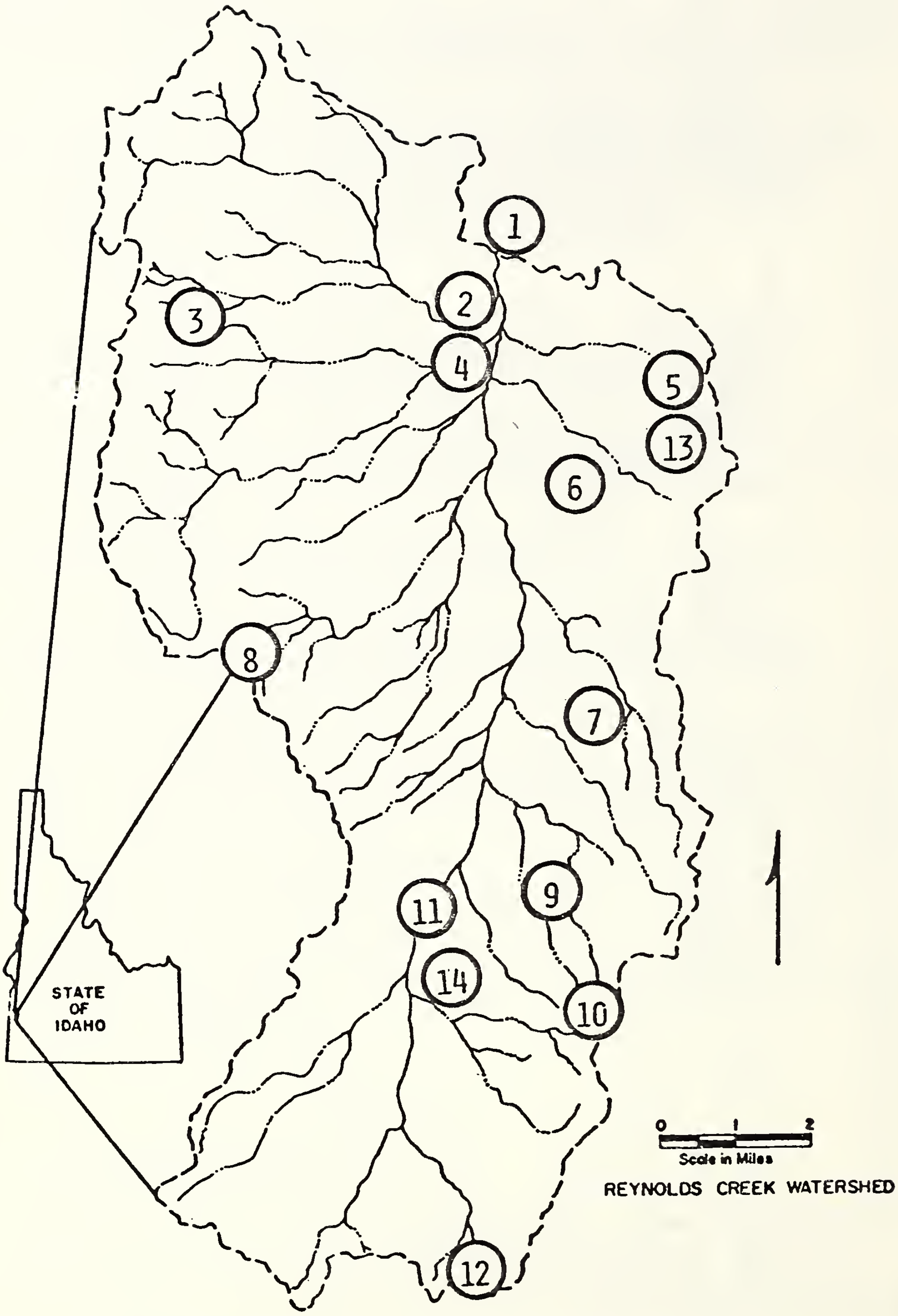


Figure 1. Locations of runoff and sediment instrumentation, Reynolds Creek Experimental Watershed, 1975.

Precipitation and runoff - 1975 water year:

Monthly precipitation and runoff from selected Reynolds Creek Watershed stations are summarized in Table 2. Precipitation at the Reynolds Weather Station was about 123 percent of the 14-year average and runoff was from 126 to 131 percent of average. Monthly precipitation amounts were above average in October, February, March, April, and July and below average in November, January, May, and September. Monthly runoff was much above average in June and July because of deep snow accumulations and a 2-week delay in spring snowmelt. Yearly peak streamflow rates for the period of record are listed in Table 3. The peaks at Tollgate and Reynolds Mountain weirs were caused by intense rainfall and snowmelt in the afternoon on June 2, 1975.

Water yield:

The average yearly water yield map, determined on a water year basis, for the Reynolds Creek Watershed, 1966-1975, is shown in Figure 2. Data from all watershed runoff stations were used to draw initial isopleths, then areas between isolines were planimetered and adjusted to fit average measured runoff. Data from the Outlet Weir, Station No. 1, Figure 1, could not be used to verify the entire map because water was diverted for irrigation.

The differences between average yearly precipitation and yearly runoff is roughly 16 inches. Yearly runoff about equals the average maximum snow accumulation at elevations above 5000 feet. Yearly water yields during the record period were about five times greater in wet years than in dry years. The average Reynolds Creek water yield, 1966-1975, is much greater than reported by Rosa.

Thunderstorm events:

Intense rainfall on July 21, 1975, following light rain on July 20, caused rapid increase in streamflow at several watershed runoff stations. Runoff and sediment production rates were greatest from the Summit Watershed (Table 1) where the peak flow was about 45 cfs and the storm sediment yield exceeded one ton per acre. Runoff from the poorly vegetated erosion plot, near rain gage 049X61 on the Summit Watershed, was 0.105 inch or about 16 percent of the storm total. Watershed runoff was only about 7 percent of the storm total. However, sediment loss per unit area from the plot was only about one-fourth that from the watershed. Storm precipitation amounts and intensities at rain gages receiving more than 0.60 inch during this storm are listed in Table 4.

TABLE 2.--Precipitation and runoff at selected stations, Reynolds Creek Watershed, 1975 water year.

Month	Weather Station 1/ Precipitation		Reynolds Creek Watershed 2/		Tollgate Watershed 3/		Reynolds Mountain Watershed 4/	
	14-year Average (Inches)	1975 Water Year (Inches)	Precipitation (Inches)	Runoff (Inches)	Precipitation (Inches)	Runoff (Inches)	Precipitation (Inches)	Runoff (Inches)
Oct.	.94	1.80	2.29	.02	2.99	.08	2.66	.12
Nov.	1.25	.71	1.37	.04	1.93	.11	2.63	.15
Dec.	1.30	1.61	1.88	.05	3.29	.13	6.93	.18
Jan.	1.36	.88	1.53	.11	2.95	.18	6.71	.22
Feb.	.66	1.64	2.43	.27	4.93	.26	10.21	.18
Mar.	.84	1.68	2.94	.62	5.85	1.01	12.84	.27
Apr.	1.04	1.77	2.58	.70	2.97	1.29	5.16	.26
May	.72	.24	.90	1.25	1.17	5.20	1.51	9.99
June	1.73	1.73	1.93	.83	1.80	4.01	2.16	13.92
July	.23	1.08	.30	.18	1.84	.86	1.31	2.32
Aug.	.72	.65	1.20	.03	1.31	.15	1.66	.23
Sept.	.46	.07	.09	.02	.15	.06	.02	.10
Water Year	11.25	13.86	19.44	4.12	31.18	13.34	53.80	27.94

1/ Reynolds weather station, 076059, Weather Service standard gage, elevation 3915 ft.
2/ Drainage area: 90 sq. mi., precipitation at rain gage 116X91, runoff at Outlet Weir, 036068.
3/ Drainage area: 21 sq. mi., precipitation at rain gage 155X07, runoff at Tollgate Weir, 116083.
4/ Drainage area: 100 ac., precipitation at rain gage 176X07, runoff at Reynolds Mountain Weir, 166076.

TABLE 3.--Yearly peak streamflow rates and dates of occurrence, selected Reynolds Creek Watershed Stations, 1963-1975.

	Reynolds Creek Outlet Weir		Reynolds Creek Tollgate Weir		Reynolds Mountain East Weir	
Water Year	Date	Peak Flow (cfs)	Date	Peak Flow (cfs)	Date	Peak Flow (cfs)
1963	Jan. 31	2331	--	--	Apr. 29	4.16
1964	Jan. 25	188	--	--	May 16	3.60
1965	Dec. 23	3850	--	--	Dec. 23	10.70
1966	Apr. 1	59	Apr. 1	59	May 5	1.43
1967	June 7	265	June 7	288	May 22	5.44
1968	Feb. 21	327	Feb. 21	186	Aug. 10	1.48
1969	Jan. 21	900	Jan. 21	405	May 12	3.88
1970	Jan. 27	729	Jan. 27	240	May 17	5.89
1971	Jan. 18	540	May 6	193	May 4	5.77
1972	Mar. 2	678	Mar. 2	271	June 6	6.26
1973	Apr. 17	166	Apr. 17	147	May 8	3.31
1974	Mar. 29	291	Mar. 29	195	May 7	4.33
1975	Mar. 25	281	June 2	231	June 2	9.27
Average		816		221		5.04

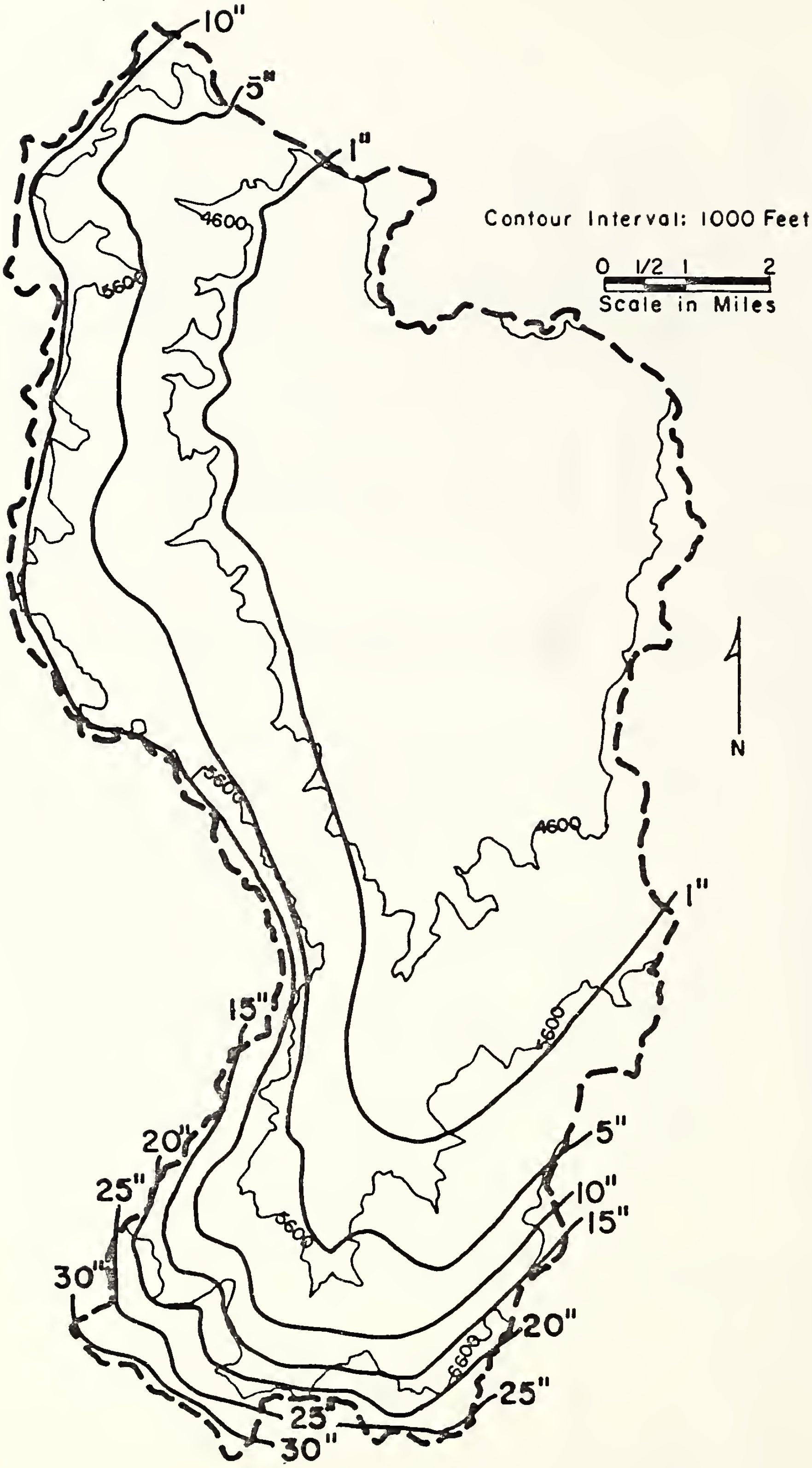


Figure 2. Average yearly water yield in inches, Reynolds Creek Watershed, 1966-75 water years.

TABLE 4.--Precipitation amounts and intensities at Reynolds Creek rain gages receiving more than 0.60 inch during the storm July 21, 1975.

Rain Gage No.1/	Storm Total	Maximum Intensity (In./Hr.)				
		5 Min.	10 Min.	15 Min.	30 Min.	60 Min.
	(Inch)					
031X48	0.68	4.80	3.72	2.48	1.24	0.62
043X41	1.22	6.00	5.40	4.08	2.20	1.10
053X93	1.18	9.00	6.00	4.60	2.38	1.20
054X23	1.47	6.00	4.50	4.40	2.60	1.30
072X67	1.07	11.76	6.30	4.24	2.12	1.06
083X92	1.22	6.00	6.00	4.40	2.38	1.22
033X76	1.00	4.20	3.00	3.00	1.54	0.82
045X04	0.72	5.40	3.48	2.44	1.36	0.83
047X52	0.61	2.16	2.10	1.48	1.16	0.58
049X61	0.64	3.96	2.22	1.92	1.22	0.61
055X88	1.37	6.00	4.08	4.00	2.66	1.37
076X59	0.80	2.40	1.80	1.80	1.36	0.80
095X10	0.90	3.60	3.50	3.20	1.60	0.85
154X64	1.08	3.60	2.70	2.60	1.70	0.96
155X07	0.61	2.40	1.92	1.40	1.12	0.56
163X35	0.95	4.80	3.12	2.70	1.56	0.78
165X02	1.58	6.00	3.90	3.40	2.72	1.41

1/ Rain gage locations are shown in Figure 1 in the precipitation section of this report.

Table 5 contains data on all intense rainstorms on the Summit Watershed, rain gage 049X61, during the 15-year period of record, 1960-1975. The number of events and measured intensities at Reynolds Creek stations are much greater than reported by Kidd from Boise and Payette National Forest records.

Peak streamflow rates at several Reynolds Watershed Weirs, caused by intense rainfall, are listed in Table 6. Generally, the intense rains caused flooding only on small areas with severe erosion, confined mainly to poorly vegetated areas where yearly precipitation is less than 15 inches. Often the most intense rain in a single storm is caught in one or a few rain gages.

Sediment yield:

Average yearly sediment yields, 1967-1974, and supporting data from ten Reynolds Creek Watersheds, are summarized in Table 7. Yields increased about ten times from dry to wet years. Also, yields from source area watersheds were consistently lower than from large watersheds, probably because of eroding stream banks and near-channel hillslopes.

A suspended sediment prediction model, using parameter optimization, showed good correlation of sediment yield with peak flow and runoff volume during identifiable runoff events. About 70 percent of the total yearly sediment yield, including bedload, was discharged as suspended sediment during these rainfall and snowmelt runoff events. Yearly suspended sediment yields during runoff events are summarized in Table 8 to compare yields computed from sampling data and from the optimization model and the Modified Universal Soil Loss Equation model at the Reynolds Creek Outlet Station, 1963-1974. The great differences in sediment yield, computed by the two models for the major floods in the 1963 and 1965 water years, result from lack of data during flood events. Generally, the optimization model overestimated yields and the modified Equation underestimated yields during flood periods. These studies are continuing, along with plans for testing the Flaxman Sediment Yield Equation.

Sediment transport:

More than 1100 suspended and bedload samples were analyzed to determine sediment transport rates from Reynolds Creek watersheds in 1975. Samples were obtained most frequently during periods of near peak streamflow. Sediment transport computations are not complete for 1975; however, preliminary streamflow and sediment transport rates for several events at the Tollgate Station are summarized in Table 9.

TABLE 5.--Precipitation amounts and intensities, 1960-75, Summit Watershed Rain Gage 049X61.[1/]

Date	Storm Total (Inch)	Maximum Intensity (In./Hr.) 5 Min.	10 Min.	15 Min.	30 Min.	60 Min.
7-30-60	0.55	3.00	1.80	1.40	0.76	0.40
6-20-63	0.22	2.40	1.32	0.88	0.44	0.22
8-31-63	0.43	1.20	0.90	0.80	0.66	0.42
6-15-64	0.46	3.00	2.10	1.48	0.84	0.42
6-16-64	0.21	2.16	1.20	0.84	0.42	0.21
11-01-64	0.26	2.52	1.38	1.04	0.46	0.24
8-03-65	1.15	4.80	4.38	4.36	2.30	1.15
8-11-65	0.46	4.44	2.70	1.84	0.92	0.46
8-20-65	0.68	2.40	1.80	1.48	1.20	0.68
8-21-65	0.42	1.20	0.90	0.72	0.40	0.30
6-22-67	0.45	1.80	1.20	1.00	0.70	0.42
6-18-68	0.35	4.20	2.10	1.40	0.70	0.35
8-09-68	0.75	2.16	1.26	1.00	0.70	0.65
8-14-68	0.75	2.04	1.50	1.04	1.00	0.52
6-05-69	0.35	2.40	1.44	1.04	0.60	0.35
6-10-69	0.37	1.20	1.08	0.96	0.72	0.36
6-19-69	0.87	2.40	2.22	1.96	1.30	0.78
6-19-69	0.20	1.20	1.20	0.80	0.40	0.20
2-12-70	0.17	1.20	1.02	0.68	0.34	0.17
5-26-70	0.36	3.60	2.16	1.44	0.72	0.36
6-23-70	0.15	1.20	0.78	0.60	0.30	0.15
5-06-71	0.55	3.00	2.22	1.76	1.06	0.53
6-04-71	0.24	1.44	0.90	0.76	0.44	0.24
8-29-71	0.55	2.40	1.80	1.40	1.00	0.55
9-06-71	0.17	1.20	0.78	0.60	0.32	0.17
6-07-72	0.73	3.00	1.98	1.48	0.82	0.43
6-08-72	0.28	2.16	1.20	0.84	0.44	0.23
6-09-72	0.24	1.56	1.02	0.88	0.44	0.22
9-05-72	0.36	1.20	1.20	1.20	0.70	0.36
4-12-73	0.16	1.56	0.90	0.64	0.32	0.16
7-14-75	0.19	2.28	1.14	0.76	0.38	0.19
7-21-75	0.63	4.20	2.64	2.00	1.22	0.61

1/ Record began 7-01-60. Rain gage locations are shown in Figure 1 in the precipitation section of this report.

TABLE 6.--Peak streamflow rates from intense rainfall, Reynolds Creek Watershed, 1965-75.[1/]

Date	Peak Streamflow Rates (Ft.^{3}/Sec.)					
	Outlet Weir	Salmon Cr. Weir	Macks Cr. Weir	Tollgate Weir	Summit Weir	Reynolds Mtn. Weir
5-23-65	353	93	30	--	--	0
8-03-65	366	88	19	--	2	0
8-11-65	221	1	0	--	3	0.1
8-20-65	520	11	4	--	25[2/]	0.2
8-22-65	326	326	76	--	100[2/]	0
8-23-65	166	659	85	--	0	0
6-01-67	121	9	10	102	1	1.5
6-06-67	183	16	10	126	0	0
6-07-67	264	10	3	288	0	2.5
6-08-67	147	14	14	120	0	1.0
6-09-67	116	9	4	84	0	0
8-14-68	134	0	0	2	26	0.1
6-08-69	106	12	2	39	0	0
6-10-69	116	6	1	60	0	1.4
6-19-69	301	2	1	24	51	0.2
6-09-72	230	94	78	79	0	0
6-10-72	140	15	13	98	0	1.4
6-05-74	110	3	1	96	0	2.0
7-21-75	240	23	59	101	45	0.8

1/ See Table 1 for watershed instrumentation descriptions and Figure 1 for station locations.
2/ Estimated, weir capacity was exceeded.

TABLE 7.--Average yearly sediment yields and other data from Reynolds Creek Watersheds, 1967-74.

Watershed		Average	Average	Average	Sediment	Sediment
NAME	No.[1/]	Elevation	Precipitation	Runoff	Record	Yield
		(Feet)	(Inches)	(Inches)	(Years)	(Tons/Ac./Yr.)
Reynolds Outlet	1	4905	20	3.2	8	0.51
Salmon Creek	2	4872	19	3.3	7	0.85
Macks Creek	4	4935	19	2.5	7	0.70
Summit	5	4475	10	0.02	7	0.34
Flats	6	3899	10	0.2	3	0.01
Nancy Gulch	7	4685	12	0.2	3	0.02
Whiskey Hill	8	5525	20	1.7	10	0.13
Upper Sheep	10	6382	18	3.0	5	0.14
Tollgate	11	6106	31	10.0	8	0.67
Reynolds Mtn.	12	6831	41	21.0	8	0.19

1/ See Table 1 for instrumentation descriptions and Figure 1 for station locations.

TABLE 8.--Suspended sediment yields computed from sediment sampling and by the prediction models for major runoff events, peak streamflow, and runoff data for the Reynolds Creek Outlet Station, 1963-74.

Water Year	Peak Streamflow	Runoff		Suspended Sediment Yield		
		Year Total	Storm 1/ Events	Computed From Sampling	Computed By Optimization Model	Computed By Musle 4/ Model
	($Ft.^3/Sec.$)	(Acre-Feet)	(Acre-Feet)	(Tons)	(Tons)	(Tons)
1963	2,331	8,889	2,887	53,900 2/	75,000	33,470
1964	188	11,791	1,882	9,100 2/	4,340	13,890
1965	3,850	33,950	18,180	248,290 2/	280,440	138,950
1966	59	3,672	108	200 2/	109	520
1967	265	10,492	2,839	11,730	5,830	20,580
1968	327	2,984	828	4,310	2,680	7,150
1969	900	17,345	4,336	38,400	37,070	32,090
1970	729	12,995	2,492	14,910	12,570	18,680
1971	540	22,996	4,899	28,100	29,980	30,110
1972	678	29,224	7,273	35,720	46,920	53,180
1973	166	8,884	761	2,170	1,660	4,720
1974	291	21,032	3,624	5,210	10,990	27,483
1975	281	19,829	-- 3/	-- 3/	-- 3/	-- 3/

1/ Includes major rainfall and snowmelt events.
2/ Inadequate sediment sampling during flood events. Sediment yields were determined by plotting available streamflow and sediment data and estimating sediment concentrations during unsampled periods.
3/ 1975 data analysis incomplete.
4/ Modified universal soil loss equation developed by Jimmy R. Williams, Hydraulic Engineer, Agricultural Research Service, U. S. Department of Agriculture, Riesal, Texas.

TABLE 9.--Preliminary sediment transport rates, Reynolds Creek at Tollgate, 1975.

Date	Streamflow Rate	Bedload Rate[1/]	Suspended Rate	Total Transport	Bedload As Percent of Total
	($Ft.^3$/Sec.)	(Tons/Hr.)	(Tons/Hr.)	(Tons/Hr.)	(Percent)
Feb. 28	63	.17	2.55	2.72	6
May 10	145	6.93	68.56	75.49	9
May 13	158	9.42	32.15	41.57	23
May 13	163	11.10	36.75	47.85	23
May 10	170	10.98	84.19	95.17	12
May 14	203	15.60	102.50	118.10	13

1/ Sampled with 3-inch Helley-Smith bedload sampler on a concrete sill, upstream from Tollgate Weir.

Sediment transport, computed from samples during a 24-hour period from noon May 14 to noon May 15, was about 208 tons bedload and 671 tons suspended load. Peak flow was 217 cfs during this period, near the maximum 1975 flow of 231 cfs. Maximum bedload transport at peak flow nearly filled the Helley-Smith bedload sampler bags in 15 seconds when the median bedload particle diameter was about 8 mm; some rocks exceeded 3 inches in diameter.

Suspended sediment samples exceeding 16,000 mg/l concentration were obtained from Peters Gulch, a tributary to Reynolds Creek above Tollgate, on May 10, 1975, during snowmelt runoff. This was the highest concentration sampled in 1975.

Soil frost study:

Severe winter floods in Idaho and surrounding areas are often caused by rain and/or snowmelt on frozen soil. Measurements of frost penetration and thawing are critical in flood analyses and watershed modeling for such events.

Frost depth has been measured weekly at about 15 locations throughout the watershed during the months of December through March from 1967 through 1975. Frost depth was measured to 4 inches; however, if the frost was deeper no measurement was made and the record indicated a frost depth exceeding 4 inches. Snow cover depth and percent of area covered by snow was either measured or estimated at each site. Soil temperatures were also recorded to a depth of 100 cm at the Quonset weather station during 1974-75.

The frost measuring program was updated in 1975 to include 11 measuring sites which were read weekly, and two sites, Reynolds Quonset and Lower Sheep Creek, where the frost depth was recorded every 4 hours. Gypsum soil water blocks at depths of 5, 10, 15, 20, and 30 cm were used to measure the frost depth at each site. Soil temperature was measured to 100 cm at the Quonset and two depths (10 cm and 20 cm) at Lower Sheep.

SIGNIFICANT FINDINGS

A water yield map for the Reynolds Creek Watershed was constructed from runoff records and average yearly yields were much higher than previously estimated. Generally, runoff is less than 1 inch per year where precipitation is below 16 inches.

Many intense rainfall events have occurred on the Reynolds Creek Watershed; however, severe flooding and erosion are usually limited to small areas with poor cover and shallow soils. Rainfall intensities exceeding 3 inches per hour for 15 minutes at 12 rain gages and intensities of 6 inches per hour or greater for 5 minutes at 7 rain gages occurred July 21, 1975.

Average yearly sediment yields were consistently greater from watersheds exceeding 12 square miles than from small source area watersheds, probably because of streambank erosion.

Suspended sediment yields, computed by the optimization model and the Modified Universal Soil Loss Equation model, differed greatly during major flood periods. Additional study is needed on application of these models to rangelands.

WORK PLAN FOR FY 77

1. Test erosion and sediment yield equations, using watershed data.
2. Test, modify, and evaluate watershed runoff models.
3. Evaluate bedload sampling equipment and measure transport rates with different flow and storm conditions.
4. Collect runoff and sediment data at active watershed stations.

REFERENCES CITED IN TEXT

Kidd, W. J., Jr. 1961
High-intensity rainstorms on the Boise and Payette National Forests, U. S. Dept. of Agr., Forest Service, Intermountain Forest and Range Experiment Station, Research Note No. 81.

Rosa, J. Marvin 1968
Water-yield maps for Idaho, U. S. Dept. of Agr. Res. Ser., ARS 41-141, March.

REPORTS AND PUBLICATIONS

Johnson, Clifton W. and Vernon S. Webb 1975
Idaho rangeland watershed management and research. Watershed Management and Symposium, ASCE Irrigation and Drainage Division, Logan, Utah, Aug. 11-13.

Johnson, Clifton W. and Clayton L. Hanson 1976
Sediment sources and yields from sagebrush rangeland watersheds. Proceedings of Third Interagency Sedimentation Conference, Denver, Colo., March 22-26.

WATERSHED MODELING

Title: Developing, testing, and evaluating watershed models

Personnel Involved:

C. L. Hanson, Agricultural Engineer	Coordinator of watershed modeling and ET modeling
D. L. Brakensiek, Research Hydraulic Engineer	Streamflow and infiltration modeling
G. R. Stephenson, Geologist	Subsurface flow and water quality modeling
C. W. Johnson, Research Hydraulic Engineer	Runoff, erosion, and sediment yield modeling
J. F. Zuzel, Hydrologist	Precipitation and snowmelt modeling
R. L. Engleman, Mathematician	Computer application and program analysis

Date of Initiation: June 1974

Expected Termination Date: Continuing

INTRODUCTION

The development of computer hardware and software over the past decade has provided the impetus for many significant advances in the development of models that simulate hydrologic components or watershed hydrologic performance. Two philosophies appear to classify modeling as either determination or stochastic. Debate on the pros and cons of the types of models is largely irrelevant. What is important is the problem to be tackled, the quality and quantity of input data and information available, and the purpose for which hydrologic predictions are required. At the Northwest Watershed Research Center, modeling activity focuses on combining and interrelating component models, such as snowmelt, infiltration, runoff, evapotranspiration, streamflow and erosion, and sediment yield into watershed models.

The watershed models provide output data for such needs as environmental impact evaluations, water quality predictions, sediment yield modeling, storm runoff models or rangeland forage productivity.

Objectives:

1. To test existing watershed models with Reynolds Creek Watershed data.

2. To improve watershed model components for a sagebrush rangeland watershed, which present models do not satisfactorily represent.

3. To utilize the models to forecast the influence of land use and treatment and/or management, such as grazing systems on watershed runoff quality and quantity.

4. To apply the watershed models to other sagebrush rangeland watersheds in the Northwest.

PROGRESS

Watershed Model:

The USDAHL-74 Revised Model of Watershed Hydrology was selected as the model to test on subwatersheds of the Reynolds Creek Experimental Watershed (Holtan, Stiltner, Henson, and Lopez, 1975). The model is now being tested and calibrated, using 1967, 1968, and 1969 data from the 205-acre Summit Basin. This watershed was selected as the first test of the model because the precipitation input is not affected by a snowpack.

After the model was operational on local computer facilities and all of the necessary input data were assembled, Clayton Hanson worked in Beltsville, Maryland with Mr. H. N. Holtan for a week to become more familiar with the model. During the week in Maryland the primary emphasis was to adjust the model to fit the soil water measurements for 1967 through 1969. During these tests no runoff was generated, indicating a need for additional parameter adjustment.

At the present time the effort is in rezoning the watershed, based on field soils data, and using the special knowledge of other staff members of the Research Center. When this has been accomplished a series of model tests will be run in an attempt to more adequately describe the runoff component of the watershed hydrology.

Suspended Sediment Prediction Model:

A conceptual model was developed to predict suspended sediment discharge (m^3) at streamflow stations by runoff event. Events were easily identified on streamflow and sediment records. Base flow data were included. Numerous small daily streamflow fluctuations were not considered events.

The model was:

$$SS = a\ (P \times V/100{,}000)^{b} \tag{1}$$

where:

SS = Total suspended sediment for the event (m^3)
P = Peak discharge (m^3/sec)
V = Total runoff (m^3)
a and b = model parameters

An optimization technique was used to obtain the parameter values for sediment yield events measured at the Tollgate, Salmon, Macks, and the Outlet Weirs. Preliminary optimization runs indicated that model parameter b was near 1.0 in most cases; therefore, data were optimized in this manner. Parameter a was then determined (Table 1). As can be seen, the optimization fits the individual station data very well. Optimization of combined station events shows a lower correlation coefficient, but r values are still highly significant ($P < 0.01$), indicating that the model can be used for prediction. Event data included about 90 percent of all suspended sediment during the period of record.

TABLE 1.--Total event suspended sediment yield, parameter values, mean yield (m^3), correlation coefficients (r), and number of events.

	Parameter		Mean		Number
	a	b	Yield	r	of events
			m^3		
Tollgate	44.5	1.0	372	0.89	92
Salmon	182.2	1.0	895	0.95	33
Macks	86.8	1.0	471	0.98	45
Outlet	35.8	1.0	2057	0.98	62
All Tollgate, Salmon, and Macks events	63.1	1.0	500	0.77	170
All Tollgate, Salmon, Macks, and Outlet events	36.6	1.0	916	0.95	232

The value of parameter a at the Outlet is about one-half or less that from the Salmon and Macks Creek watersheds, which indicates that considerably more suspended material is being transported from this watershed than from the whole Reynolds Creek Watershed under comparable runoff conditions. The value of a for the Tollgate watershed indicates relatively less suspended sediment from snowmelt areas.

Boise River Ecologic Model:

Due to time limitations for data gathering, we were unable to pursue testing this model on the Reynolds Creek Experimental Watershed during 1975.

Infiltration Process Modeling:

Development of a procedure for estimating the parameters for the Green and Ampt infiltration equation was continued during 1975. This formulation is simple, but is based on obtainable physical soil properties. Existing infiltration data on file are being utilized to estimate the parameter values for the Reynolds Creek Experimental Watershed sites.

Precipitation and Snowmelt Modeling:

(Progress is reported under precipitation and snow sections.)

References:

Holtan, H. N., G. J. Stiltner, W. H. Henson, and N. C. Lopez. 1975. USDAHL-74 Revised Model of Watershed Hydrology, USDA, Tech. Bul. No. 1518. 99 pp.

SIGNIFICANT FINDINGS

Information to date indicates that the USDAHL-74 Model can simulate soil water relatively well on an annual basis. The model was developed for crop type lands and, thus, does not evaporate or transpire water fast enough during the cool part of the year on rangelands, and then uses it too fast during spring and early summer. Some of this problem can be alleviated by adjusting parameters. The present model does not have a good snowmelt routine or account for frozen ground conditions. These two shortcomings must be corrected before the model will adequately predict northwest range watershed hydrology.

The suspended sediment prediction model, using parameter optimization, shows excellent correlation between peak flow and runoff volume and suspended sediment amounts for identifiable runoff events. Application of this model to other streams with long-term runoff records should require sediment records from only a few events to determine values of parameter a. Studies relating model parameters to watershed characteristics are continuing.

WORK PLAN FOR FY 77

1. Continue testing and adapting the USDAHL-74 Model of Watershed Hydrology to the Summit Basin and other subwatersheds of Reynolds Creek Experimental Watershed.

2. Development will continue on specific input parameters and/or revise model components for the USDAHL-74 Model of Watershed Hydrology to better model rangeland ET, infiltration, and channel flow.

3. Snowmelt forecast models will be further refined and tested.

4. Evaluate possible forage production forecasting equations.

REPORTS AND PUBLICATIONS

Hanson, Clayton L., Earl L. Neff, and David A. Woolhiser 1975
Hydrologic aspects of water harvesting in the Northern Great Plains. Proceedings of the Water Harvesting Symposium, Phoenix, Arizona, March 26-28, 1974. USDA-ARS, ARS W-22, February 1975, pp. 129-140.

Johnson, Clifton W. and Clayton L. Hanson 1976
Sediment sources and yields from sagebrush rangeland watersheds. Accepted for publication in the Proceedings of the Third Federal Interagency Sedimentation Conference, Denver, Colo., March 22-26.

Zuzel, J. F., D. C. Robertson, and W. J. Rawls 1975
Optimizing long-term streamflow forecasts. Journal Soil and Water Conservation 30(2): 76-78, March-April.

Zuzel, J. F. and William T. Ondrechen 1975
Comparing water supply forecasting techniques, Proceedings of Watershed Management Symposium--Irrigation and Drainage Division, ASCE, pp. 327-336, August.